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ABSTRACT

This study proposed to gather as much material as possible about the teaching of high school physics, including material on classroom teaching methods, the type of instructional material in use, the background and objectives of the teachers, and the students' experience and attitude towards physics. The procedures included prestudy questionnaires of teacher qualifications, lab facilities, and required texts of a sample group of 45 high schools in the northeastern United States. An investigator visited the schools to observe and record classroom activity, interviewed teachers and students, and accumulated checklists of facility and policy requirements. Generalizations about the teaching of high school physics today were drawn. (Included are appropriate analysis tables and samples of the questionnaires and checklists.) (JA)

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HIGH SCHOOL PHYSICS TEACHING: A REPORT ON CURRENT PRACTICES

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Introduction

Very often, physics educators ask questions such as "How many high school teachers use the PSSC materials?" or "Which of the newer high school textbooks is most popular?" Surveys capable of answering questions like these are not difficult to perform, but the staff of the Education Division at the American Institute of Physics (AIP) has consistently resisted the temptation to conduct a completely objective survey of this kind. We felt certain that no paper and pencil questionnaire which offers only a limited array of preconceived responses could possibly reveal the complexity of the pedagogical strategies and the mixtures of materials actually used by high school physics teachers. Discussion of the need for an in-depth survey to explore actual teaching practices took place between AIP staff and Charles Whitmer, Howard Hausman, and Larry Binder of the Precollege Science Division of the National Science Foundation (NSF) over a number of years. These discussions led to a grant from NSF to AIP for this Study of High School Physics Teaching in February of 1971.

Other essential ingredients in this effort were the interest and skill of the investigators from Teachers College, Columbia University. The AIP staff has neither the time nor competence to conduct an in-depth study of the kind it felt was needed. Fortunately, the AIP Education Division Director, A. A. Strassenburg, and Professor George Ivany of the Science Education Department at Teachers College had discovered their mutual interest in high school physics teaching while working together on a Commission on College Physics project some years earlier. These mutual interests led naturally to cooperation on this Study of High School Physics Teaching. In actual fact, Professor Ivany and three of his graduate students, Douglas Huegel, Richard Mullaney, and Russell Faust collected and analyzed the data. A. A. Strassenburg served as Chairman of the Advisory Committee; other members were Roger Anderson, Teachers College, George Ivany, Richard Mihm, Glastonbury (Connecticut) High School, and Clifford Swartz, State University of New York at Stony Brook.

It was agreed from the beginning that the goals of the study would be to learn as much as possible about classroom teaching methods, the type of instructional materials in use, the backgrounds and objectives of the teachers, and the physics experiences and attitudes toward science of the students. It was also agreed that the information would be collected during one-week visits to 45 high schools in the northeastern states of the U. S. (The number, length, and geographical limitations on the visits represent compromises between optimizing the probability of collecting sufficient valid data and minimizing the cost of the survey.) During a visit, the investigator observed and recorded classroom activity, conducted interviews with students, faculty, principals, and counsellors, collected biographical data from and sampled the opinions and attitudes of students and teachers, and completed checklists concerning facilities, policies, and teaching practices of the schools. Both the procedures and the results of the study are described in the report that follows.

As interesting as the results of this study will surely be to those who are convinced of the important role of high school science in the education of future scientists and the general public, something more than answers to immediate factual questions motivated those who invested time and money in this effort. Almost all educators are distressed that current instructional practices are not more effective. Many are innovating in one way or another in the hope that significant improvements will result. The

obvious question is, "Do innovations really produce a measurable improvement in student learning?" On the surface, it often seems that the answer is "no." Yet we continue to try new methods, in the hope that we will produce a breakthrough in instructional practice. In some cases, huge sums of money and many man-years of time are invested with no more than our confidence in creative individuals to generate optimism. Only the important consequences of success could justify these efforts. Perhaps real gains do result, but are difficult to detect among the noise of complex events and interlocking variables. The detection of a positive signal under these conditions would provide the guidance vital to the optimization of future efforts. But before gains can be claimed when a new method is tried, one must know with some accuracy what situation existed prior to the change. Unfortunately, few researchers have taken the necessary pains to describe adequately the ambient situation with regard to high school physics teaching; therefore meaningful before-and-after comparisons have been difficult to make. The main purpose of this study is to provide that much needed baseline information. Hopefully others will conduct similar studies in the wake of future innovations so that assessments can be made of the contributions that specific new techniques and materials make to the effectiveness of high school physics teaching.

THE STUDY: AN OVERVIEW

To collect the baseline data on the status of physics teaching in high schools sought by this study, a number of techniques were used. The major data collection period was a week long visit to each school by one of the study associates. Prior to the visit a number of questionnaires and data forms had been sent to the teacher involved. These were designed to help the investigators collect background information on the teachers, to guide the teachers in recording daily classroom activities for about ten weeks prior to or immediately after the visit, and to establish procedures for the visit. During the week of visitation the techniques for data collection ranged from checklists filled out by the research team to observations, paper and pencil tests, and interviews. A brief description of the instruments will be presented here. A complete set of these appears in the Appendix.

The description of physics teaching undertaken here focuses on three dimensions: the teacher and his pedagogical strategies; the teaching learning environment; and the student and his higher order understanding and appreciation of physics. None of these dimensions is a simple, one-sided affair, but each is seen, rather, as a frame of reference for different kinds of data to be measured by one or more means.

The Teacher and His Pedagogical Strategy

1. Personal Profile: The usual basic information on the training, experience, professional involvement, and school duties of the teacher.

2. Curriculum Summary Sheet: The daily classroom activities, a curriculum summary, and an overall summary for each of ten weeks around the intensive week of visitation. The investigators attempted to record the exact nature and sequence of curriculum events--text, A. V. material, laboratory exercises, demonstrations, assignments, etc.

3. Classroom Observations: Anecdotal records of events witnessed during the week of visitation kept by the research team. In addition, audio recordings of class and lab sessions were made for future analysis.

4. Teacher Interview Schedule: An assessment of the extent to which the teacher is guided by a developed philosophy of physics and physics teaching and a consistent set of objectives for the course.

The Teaching - Learning Environment

1. Facilities Check List: An assessment of the adequacy of the physical plant and budget for support of a modern physics course.

2. Curriculum Resources Check List: An assessment of the adequacy of available and/or accessible curriculum materials to support the intentions of the teacher. A special effort was made to identify the resources dictated by new course adoptions.

3. Physics Teaching Opinionnaire: The students' perceptions of the

teaching - learning atmosphere, the demands of the teacher, and the objectives of the course.

4. Selected Interviews with Department Chairmen, Guidance Personnel, and Principals: An attempt to ascertain the philosophy of the school, its status with regard to innovation, the professional dialogue available to physics teachers, and the role of the guidance department in counselling with respect to science, particularly physics.

The Student

1. Classroom Observations: Information about the behavior of physics students. This was supplemented with anecdotal information.

2. Science Opinionnaire: An attempt to reveal student attitudes toward science and the science-society-technology interface.

3. Student Interview Schedule: An assessment of the epistemological status of the students' knowledge of physics.

I. SCHOOLS AND FACILITIES

Selecting the Sample Schools

The study focussed on physics teachers and their classrooms. The selection of 45 schools was made from 11 Northeastern states and Washington, D.C. The investigators anticipated that about half of the schools contacted would be willing to participate, therefore a mailing list of about 90 schools was randomly selected initially. However, a completely random selection from among the schools within the study area was felt to be inappropriate, because a random sample of only 45 might not reflect adequately a number of significant variables. In order to produce a sample that reflected the secondary school enrollment in the various states and in communities of various sizes, the investigators added more schools and the mailing list grew to 107 schools. Table 1 indicates the distribution by state of the original mailing list, and the distribution of schools in the actual sample by community size and by state. By the time the study actually began, the sample had dropped to 42 teachers and classes as a result of late withdrawals. Maryland and Rhode Island were not represented in the final sample because of these late withdrawals.

Table 1 also reveals that fewer urban schools were willing to cooperate than schools in any other type of community. The urban schools in our sample were also less able to provide data and access to information than were schools in smaller communities. We believe that similar difficulties would also have been encountered in other large city schools.

Description of Sample Schools

The schools from which the sample teachers were selected are quite varied in ways other than geographic. Total school enrollments range from 210 to 4500. Total physics enrollments range from 8 to 172; total enrollments in some high school science range from 58 to 1577. The number

TABLE 1: SAMPLE SCHOOLS BY STATE AND COMMUNITY TYPE

	URBAN	SUBURB	RURAL	SMALL CITY	TOTAL	MAILING LIST
CONNECTICUT	1	3		2	6	6
DELAWARE				1	1	4
MARYLAND						7
MASSACHUSETTS	1	1	1		3	16
MAINE		1			1	4
NEW HAMPSHIRE			2		2	5
NEW JERSEY		5	1		6	14
NEW YORK	2	9	1		12	25
PENNSYLVANIA	1	3	2	2	8	18
RHODE ISLAND						2
VERMONT			1	1	2	3
WASHINGTON, D.C.	1				1	3
TOTALS	6	22	8	6	42	107

of teachers in a school offering a course in physics ranges from one to three.

Table 2 shows the percentage of 12th grade students taking a physics course according to the type of community in which the school is located. For the entire sample the percentage is 20.9, with a definite change from low to high enrollment percentages as one goes from inner city schools to more affluent suburban areas.

TABLE 2: PERCENTAGE OF STUDENTS TAKING PHYSICS

Population	Number of Schools	Percentage of 12th Grade in Physics
Urban	6	12.0
Small City	6	13.5
Suburban	22	23.4
Rural	8	18.8
Entire Sample	42	20.9

Although no special effort was made to record long term enrollment trends for the sample schools, the changes from the previous year to the study year (1971-72) were noted. Over the total sample of 42 schools there was an increase of only 27 students enrolled in physics from the previous year, something on the order of 1% of the total enrollment. The only large increases were due to new adoptions of the Project Physics (PP) course. However, schools where the PP course is an ongoing curriculum are no better at retaining students than schools using other courses. By contrast enrollments in chemistry in the same schools increased by 11% in the same year.

In Table 3 we present the financial support provided for the science program divided over three community types: urban, suburban, and others. The size of school is also considered as a variable having two values, large and small; an enrollment of 1500 was selected as the cutoff figure. Some words of caution are needed here: most of the figures represent actual physics program expenses. However, in some instances these data were not separable from total science department budgets and in such cases we have assumed an equal division of available funds across science areas.

As can be seen in Table 3, the range of budgeted support for physics is wide. Some of the extreme cases at the high ends of the scales for capital and expendable budgets can be explained in terms of new course adoptions. Thus a school having adopted a new PP course during the study year shows inflated figures for that year only. However, several other schools, usually in affluent suburban neighborhoods, indicate considerable support on a continuing basis. Of particular interest is the fact that only 7 of the 42 sample schools provide support for laboratory assistants.

TABLE 3: FINANCIAL SUPPORT OF PHYSICS PROGRAMS

BUDGETS (Dollars per student per year)		URBAN (6 schools)		SUBURBAN (22 schools)		RURAL-SMALL TOWN (14 schools)		TOTAL		
		L	S	L	S	L	S	L	S	Combined
Capital	0-4.99	3	1	5	2	1	6	9	9	18
	5-14.99			1	5		2	1	7	8
	15-	1'		4	3		4	5	7	12
	N.R.	1		2		1		4	0	4
Expendables	0-2.49	1	1	3	2		6	4	9	13
	2.50-5.00	2		3	4		4	5	8	13
	5.00-	1'		4	4	1	2	6	6	12
	N.R.	1		2		1		4	0	4
Laboratory Assistant on Salary		1		3	2		1	4	3	7

Footnotes:

Large Schools (L)--over 1500 students
Small Schools (S)--up to 1500 students
1' means that the figures for this school include extra expenses caused by a new adoption.
N.R. indicates schools that are otherwise not represented on this table.

Curricula

With only minor variations the science curriculum sequence available in the sample schools is the traditional Biology-Chemistry-Physics pattern. In the grade prior to this main sequence there is greater variety. Eight schools offer the IPS course, eleven schools offer an earth science course which in three instances was the ESCP program, one school offers the newer ISCS program, and most schools offer either a general or physical science course of a somewhat local variety.

In Table 4, data is presented on the variety of physics courses offered in the sample schools. These are not the classes studied in depth in this study, but rather the courses offered in the schools visited. The purpose of the table is to provide background information about the kinds of schools from which sample classes were selected. Naturally, the combined figures add up to more than 42 since many schools have more than one offering in physics. The table shows that in 19 of the 42 schools, some version of the PSSC course is available. Project Physics is offered in 10 schools.

TABLE 4: COURSES OFFERED BY TYPE OF SCHOOL

	URBAN		SUBURBAN		RURAL-SMALL TOWN		TOTALS		
	L	S	L	S	L	S	L	S	Combined
Total No. Schools	5	1	12	10	2	12	19	23	42
PSSC	2	1	6	5	1	4	9	10	19
PP	0	0	5	5	0	0	5	5	10
Modern-Traditional	5	1	8	7	1	8	14	16	30
Advanced Placement	1	0	2	1	1	0	4	1	5
Misc.	c,c	-	b,d,e	-	a	c	6	1	7

Footnotes:

1. L (Large) and S (Small) schools defined as in Table 3.

2. a - F.U.S.E.
   b - Electronics
   c - "Practical" physics courses
   d - Local course, PSSC and PP
   e - Astronomy

The term modern-traditional needs some explaining. Grouped here are a number of new physics courses which are defined by a published textbook in the traditional way. However, for the most part, (and with one or two exceptions), the books are quite innovative and modern. Several of them show influences from the N.S.F. project courses; some even exceed them in some aspects of innovation. Thus the group "Modern-Traditional" is a rather mixed one, useful more for purpose of contrast to the nationally supported projects rather than for indicating a single philosophy of pedagogy. A list of the texts grouped according to this heading showing the number of schools where they occur is given in Table 5.

TABLE 5: MODERN-TRADITIONAL TEXTS BY SCHOOL USE

	No. Schools
Modern Physics Williams, Metcalf, et al	8
Physics Taffel	4
Modern College Physics White	3
Foundations of Physics Lehrman & Swartz	1
Matter and Energy MacLachlan	1
Physics for High School Miner & Kelly	1
Physics: Fundamentals and Frontiers Gamow, George	1
Exploring Physics Brinckerhoff, et al	1
Exploring Modern Physics Efron	1

A general view of the science curriculum in the sample schools reveals a pattern of innovation generally. During the past decade all but three of the schools have adopted anywhere from one to six of the new science courses developed by nationally supported groups of scientists. Among those offered by the schools in our sample during the year of the study were: PSSC, PP, CHEMS, CBA, BSCS, IPS, ESCP, IIS, and ISCS.

School Facilities

A description of available facilities for physics teaching is a complex thing. For many variables (such as amount of chalk board surface) there is no obvious way to display 42 distinct pieces of information in some averaged form which would make sense. Instead it would seem useful to focus upon a small number of items which seem significant for science teachers. These will be described in terms of the range of facilities in the sample schools.

In 39 of the classes visited the classroom and laboratory are a combined room. Only 9 of the teachers use a room which is solely the domain of physics. This makes it awkward to leave apparatus or projects "up" from period to period. Three classrooms have no demonstration table. Of the other 39 with demonstration tables, five have no water, four have no gas and only 18 have a variable electric source. However, 40 teachers have access to variable, portable power units. The room seating capacity ranges from 18 to 36, with 24 being the average. Only 17 of the 42 schools have flexible seating arrangements in the physics room. Space for apparatus storage is at a premium; 22 schools have inadequate storage space according to the teacher. On the other hand, 27 schools provide preparation areas for the teacher which are separate from the laboratory. Laboratory bench utilities include gas (35 schools), water (34), variable electricity (30), but rarely air (1) or vacuum (6). Twenty-one schools have a dark room for photography.

Audio visual facilities are equally varied. Thirty-seven schools have projection screens in the physics room, but seven of these rooms can not be darkened. Ten of the schools provide coaxial cable for television to the physics room. Only one room can be divided by means of flexible partitions. Twenty-six schools have no space for individual special projects. Nineteen teachers have access to some machine shop facility.

Twenty-eight school libraries of the forty-two studied have a physics section, and in eleven schools this is supplemented by a small physics library in the room. Individual carrels for students, equipped with A.V. facilities, are available in one physics room, and in thirteen other schools such facilities are available in the library.

In order to check on the adequacy of physics laboratory apparatus, especially items not in routine use, a check list of several items was prepared. Table 6 shows the number of schools owning specific pieces of equipment. About half of the twelve schools which use computers have only an electronic (but programmable) calculator rather than a full computer facility. However, several schools operate a full computing science facility, and in one instance the computer features both batch processing and "on line" capability. There seems to be little doubt that in most of the schools where computers are available, they are administrative rather than instructional devices, as might be expected.

TABLE 6: SAMPLE SCHOOLS OWNING SELECTED LABORATORY EQUIPMENT

	Available	Not Available	No Response
Power Supply Units	40	1	1
Air track	21	18	3
Laser	17	22	3
Optical Bench	20	18	4
Cathode-ray Oscilloscope	35	4	3
Microwave Experimenter	17	23	2
Spectrometer	29	13	-
Rotational Dynamics Apparatus	21	18	3
Electronics Kit	19	20	3
Polaroid Camera	20	18	4
Analytic Balances	22	18	2
Telescope	12	25	5
Computer	12	22	8

Program Constraints

The constraints perceived by teachers and by administrators which operate on the physics program were of concern in this study. The question was posed specifically with regard to the decision to adopt a new course, or to innovate in other ways within the physics program. Table 7 shows the responses of the two groups in terms of the percentage of each group perceiving a list of factors as constraining. It is interesting to note that 8% of the administrators felt that teachers were a constraint upon innovation whereas 28% of the teachers pointed to school policy and 45% to school schedule, both items in the domain of the administration.

TABLE 7: CONSTRAINTS ON PHYSICS PROGRAMS

As Perceived by Principals		As Perceived by Physics Teachers
50%	Space	48%
34%	Budget	35%
3%	Policy	28%
24%	Schedule	45%
11%	External Exams	5%
11%	Community	5%
8%	Teacher	-

II. TEACHERS

The Background of the Teachers

The accurate assessment of a teacher's academic background requires considerable cooperation on his part. Many teachers were unable to easily remember the past courses taken in a variety of disciplines. The result is that only 32 of the 42 teachers could completely identify and specify

their preparation as physics teachers. Table 8 describes this preparation in blocks of ten semester hours in the traditional disciplines and preparation in professional science education courses. The mean number of semester hours in physics for this group is about 42 which is considerably higher than the 18 reported by the Panel on the Preparation of Physics Teachers of the Commission on College Physics in 1968.[1] However, the figures presented here are in good agreement with the report of a study of physics backgrounds of teachers in the state of Wisconsin.[2]

Naturally, some of this unexpected preparatory excellence is due to the nature of the sampling. Teachers who are unsure of themselves because of a poor background in physics were no doubt dissuaded from participation in the study. Nevertheless, the results were unexpected and heartening.

During the past decade of new curriculum activity the presence of the N.S.F. summer and academic year institutes and other similar programs have greatly influenced teachers. Another interesting aspect of the background of the sample teachers, then, was the extent to which they had attended institutes devoted to the support of the pedagogical ideas of the PSSC or PP courses. It is equally interesting to attempt to match the kind(s) of institute attended with the type of course being offered back in the classroom. Table 9 shows such a breakdown. It also illustrates a fascinating problem of classroom description. Rarely is one able to find a "pure" curriculum operating. In most instances teachers operate in an eclectic manner, picking and choosing what seems appropriate, what they know, are interested in, or have equipment for. Thus the teacher-curriculum breakdown presents under the "Modern-Traditional" label 23 classes, only 7 of which operate solely out of a given textbook. The other 16 classes adopt a modern-traditional textbook, but readily use laboratories, exercises, films and readings from either the PSSC or PP courses. Note that of the nine teachers who had attended a PSSC institute, only three offer a "pure" PSSC course, though all of the other six freely use PSSC materials in their courses. Also, of the eight teachers who attended Harvard Project Physics institutes, five are using PP materials in their teaching. It would seem fair to conclude that institutes seem to have an effect upon the teachers' pedagogical style. Only two teachers of a total of 21 who had attended institutes specifically geared to the PSSC or PP courses are continuing to teach a course without adding materials from one or other of the "new" curricula. One of these two happens to be awaiting the arrival of a full set of PP materials, having convinced his school of the value of an adoption.

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[1] P.P.P.T., "Preparing High School Physics Teachers," a report to the Commission on College Physics, College Park, Maryland, 1968, page 5.

[2] Don Dietrick, "A Comparison of Selected Wisconsin Secondary Schools," paper delivered at annual meeting of the National Association for Research in Science Teaching, Chicago, April, 1972.

TABLE 8: UNDERGRADUATE AND GRADUATE STUDY CREDITS OF 32 TEACHERS BY DISCIPLINE

Number of Semester Hours	BIOLOGY		CHEMISTRY		PHYSICS		MATHEMATICS		SCIENCE EDUCATION	
	No. of Teachers	%	No. of Teachers	%	No. of Teachers	%	No. of Teachers	%	No. of Teachers	%
0-10	21	65.5	14	44.9	5	17.2	3	6.9	21	65.5
11-20	3	10.3	8	20.7	1	3.5	9	28.0	8	24.5
21-30	6	17.2	5	17.5	3	6.9	13	44.9	3	10.3
31-40	1	3.5	2	6.9	11	32.2	5	13.6	0	0
41-50	1	3.5	2	6.9	4	13.6	2	6.9	0	0
51-60	0	0	0	0	4	13.6	0	0	0	0
61-	0	0	1	3.5	4	13.6	0	0	0	0
Mean Number of Semester Hours	10.2		18.9		41.7		23.4		10.8	

TABLE 9: CURRICULA VERSUS ATTENDANCE AT INSTITUTES

CURRICULUMS	INSTITUTES				
			PSSC &		
Traditional	PSSC	HPP	HPP	None	Unknown
7 Modern-Traditional		1	1*	4	1
10 Traditional with PSSC	2	1	1	2	4
6 Traditional with PSSC & PP	3	2	1		
PSSC					
7 "Pure" PSSC	3			4	
4 PSSC with Traditional		1		3	
1 PSSC with PP					1
2 PSSC with Traditional & PP		1	1		
PP					
4 "Pure" PP		2			2
1 PP with PSSC	1				
TOTAL	9	8	4	13	8

*Will become PP classroom as soon as materials arrive.

Perhaps of additional interest in describing the sample teachers would be a look at the extent to which they read professional journals. Two thirds of the teachers receive The Physics Teacher, one half receive Scientific American, one third Physics Today, one quarter The Science Teacher, and one tenth The American Journal of Physics.

Any consideration of teacher background would be incomplete without acknowledging the role of prior experience. The experience of teachers in our sample ranges from a maximum of 22 years down to one year. All levels of teaching are covered from elementary school to college level instruction. The mean number of years of teaching experience for the total sample is 9.6.

Philosophies and Intents

A knowledge of the conceptual postures of physics teachers toward physics knowledge and physics teaching is of fundamental importance in attempting to understand physics classrooms. It is the teacher who serves as the primary and immediate authority for the interpretation of the meaning of physics knowledge; it is the teacher who initiates or sanctions events and activities which occur in the classroom. It seems probable that a teacher's prior-to-the-act conceptualization of physics and teaching influences nearly every aspect of classroom life.

In an attempt to describe the teachers conceptual postures, an interview schedule of nine questions was developed. The questions attempted to probe the teachers' conceptualizations of physics and teaching and the interaction between these condeptualizations. The interview sessions were freely structured conversations between the physics teacher at each school and the researcher; each interview was firmly guided by the nine questions. The average duration of each interview was about forty-five minutes. The information gathered during the interviews was recorded and is presently undergoing extensive analysis; much of it will be reported at a later time. However, each interviewer was provided with a checklist to record the more obvious and predictable responses tnat a teacher might give; this data is reported here along with the nine interview questions. The first six questions deal primarily with the teachers' views on teaching and pedagogy; the last three questions are directed at the teacher's view of science, especially physics.

> Question #1: Do you think the views of students in general towards studying physics in your high school are undergoing changes? How about their attitudes towards further physics study or physics oriented careers. Would your answer be the same in both cases?

Twenty-seven of the forty-two teachers think that student attitudes towards studying high school physics are undergoing changes. Fourteen of these think that the students attitudes are becoming more positive. In response to the second part of the question, nineteen teachers stated that student attitudes toward further physics study or related careers are undergoing change. Of these, only six teachers think that the attitudes are becoming more positive.

Nineteen of the forty-two teachers mentioned that recent innovations in their physics program had been a factor in attracting students to their classes. However, eight teachers thought that the general economic condition of the country was a factor which influenced some students to stay away. More importantly, eighteen teachers mentioned that the general alienation of some youths toward modern society was a factor which kept some students from choosing to take physics classes.

When these same three factors were investigated in teacher responses about student attitudes towards further physics studies or physics oriented careers, only one teacher mentioned recent physics program innovations as being a positive factor, while nineteen teachers mentioned general alienation as being a negative factor.

In summary, fourteen of the teachers think that student attitudes toward taking high school physics are improving. The most powerful factor with a positive influence in this choice seems to be program innovation; the most powerful factor influencing this choice negatively seems to be the general alienation of some youth toward society. Only six teachers feel that student attitudes toward further physics studies or physics related careers are becoming more positive; the only powerful factor influencing the students here seems to be the perceived economic condition of the country.

Question #2: What approach to physics education in high school seems most appropriate to you? That is, which students should take physics and what should be the overall nature of the course/s?

The responses of the teachers were scored in the following manner. Four types of students were recognized: those who planned to pursue a science major in college, those who planned to pursue a liberal arts degree, those who planned to pursue a one or two year technical school certificate, and those whose formal education would be terminated on graduation from high school. Five major approaches to physics education were suggested by the physics teachers for the various student types: no physics, a practical-applied-technology course, a traditional-mathematical-problem solving course, an experimentally-oriented course, and a course with a cultural-historical orientation. Some teachers suggested that either of two courses would be appropriate for a given type of student; some teachers had no opinion. The data is reported in Table 10.

TABLE 10: NUMBER OF TEACHERS PREFERRING SELECTED CURRICULA FOR SPECIFIC STUDENT GROUPS
(Question 2)

	None	Applied	Modern-Traditional	Experimental	Cultural Historical
Science	0	2	10	22	11
Arts	3	6	7	5	22
Technical	6	7	5	4	19
Terminal	11	9	2	0	14

The most notable aspect of the data is that the teachers feel that the experimental physics course is a suitable experience almost exclusively for those students who are going to be college science majors while the cultural-historical course is seen as being adaptable for all students.

Question #3: In your particular course in physics do you have a specific set of objectives which you strive to reach? i.e., Why do you teach physics?

The teachers were initially allowed to answer this question in their own way. They were then given eight typical physics teaching objectives, each typed on a 3 by 5 card, and asked to sort the cards and rank them according to their belief as to the importance of each objective. The objectives were formulated so as to be based in part on the taxonomy of cognitive objectives listed by Bloom, et. al. (1956). The objectives are:

1. Possession of knowledge about important facts, laws, and theories of physics.

2. Knowledge of the methods physicists use to discover and validate knowledge in physics.

3. Knowledge of the cultural and historical aspects of physics.

4. A verbal and mathematical understanding of the topics covered in physics.

5. Increased understanding and approval of the role of the scientist in our culture.

6. Skills derived from laboratory manipulation of common physics apparatus.

7. Ability to use some general techniques of data analysis such as: consideration of errors, numerical statistics, and graphical display.

8. Increased interest in physics as evidenced by outside reading and discussion about topics in physics.

The resulting rank order for forty-one teachers was obtained by assigning weights from eight to one for each position that a card might occupy (the card in first position receives eight points, etc.) and summing over the products of the frequency of occurrence of a given card in a position times the weight of the position. The objectives were then ranked according to the total number of points received. The results:

Objective No.:	1	2	3	4	5	6	7	8
Score:	173	198	154	240	150	181	192	183
Rank:	6	2	7	1	8	5	3	4

The teachers' objectives, then, may be listed in rank order as:

Objective No.:	4	2	7	8	6	1	3	5
Score:	240	198	192	183	181	173	154	150
% Score Received:	16	13	13	12	12	11	10	10

The bottom row, % score received of the total possible score, provides a convenient scale for displaying the data on a graph. This is done in the following three tables along with additional data that was also obtained from the card sort.

TABLE 11: RANK ORDER OF OBJECTIVES OF TEACHERS
(Question 3)

% of Total Score	All (41)	Mod. Trad. (17)	Trad. Comb. (5)	PSSC (14)	PP (5)
18					8
17		4			4
16	4		4	2	
15			2	4	
14		1,7	1		
13	2,7	6		5,7	6
12	1,6,8	2,8	5,7	3	
11			6,8	6,8	3,7
10	3,5	3			1,2,5
9			3	1	
8					
7		5			

TABLE 12: TEACHER OBJECTIVES AS PERCEIVED BY STUDENTS (Question 3)

% of Total Score	All (194)	Mod. Trad. (83)	Trad. Comb. (24)	PSSC (64)	PP (23)
18			1		4
17	4	1,4			
16			7	4	1
15	1	7	2,4	7,1	
14	2,7	2		2	
13	6	6	6	6,8	2,7
12					8
11					6
10	8	8			
9	3		8		3
8		5	5	3,5	5
7	5	3	3		

TABLE 13: OBJECTIVES PREFERRED BY STUDENTS (Question 3)

All (189)	Mod. Trad. (83)	Trad. Comb. (20)	PSSC (63)	PP (23)
				4
		4		1
4	1,4		1	
1		1	7	
2	2	2,7	4	
6,7	6		6,8	2,7
	7,8	6	2	8
8				6
5	5	8	5	
		5		5
3	3	3		
			3	3

Each column in Table 11 displays the rank order of the card sort objectives for different groups of teachers. Starting at the left, the first column displays the objectives in rank order grouped for all the teachers; this is the data that has been discussed above. The next four columns illustrate the same data when the teachers are grouped according to the curriculums that they teach. These curriculums are: modern-traditional curriculum, traditional curriculum which combines PSSC and PP materials, the PSSC curriculum, and the PP curriculum. (The distinctions between these curriculums are discussed in the following section on Teaching). Tables 12 and 13 display the resulting rank orders of objectives done by students randomly selected, five from each class. The first of these, Table 12, displays the students' perceptions of their teachers objectives as inferred from normal class activity; and Table 13 displays the students' objectives as they would like them to be, or their class objectives as they "ought to be." The student card sort data is again broken down by curriculum in the right hand columns of Tables 12 and 13.

In trying to make sense of these three tables, it is useful to consider that if the teachers and students were not able to distinguish between the objectives, or if the groups had no strong preferences, each of the eight objectives would receive approximately 12.5% of the possible total score. The brief discussion to follow, then, will mostly deal with the objectives which the groups have especially favored by awarding 15-18% of the score, or especially disliked by awarding only 7-10% of the score.

The objective receiving the highest score in each of the three analyses is objective #4, a verbal and mathematical understanding of topics covered in physics. The popularity of objective #4 is high in all the curriculum subgroups.

The students perceive objective #1, possession of knowledge about important facts, laws, and theories of physics, to be an important objective of their teachers, which it is not; moreover, they think that it ought to be considered important. The extent of this discrepancy is apparent when the PSSC teacher group picks objective #1 as the objective that they think ought to be least favored. A similar situation exists in the PP subgroup.

Objectives #3 and #5, knowledge of cultural and historical aspects of physics, and increased understanding and approval of the scientist in our culture, respectively, are in disfavor with the "all teacher" and both "all student" groups. The students maintain their disfavor for these objectives across all the subgroups, but for the teacher subgroups these objectives become more positive, especially for PSSC teachers.

A final comment should be made about the extremely favorable rating given by the PP teacher subgroups to objective #8, increased interest in physics as evidenced by outside reading and discussion about topics in physics. No other subgroups gave objective #8 a favorable rating. Again, the PP student subgroup does not perceive that objective #8 is an objective favored by their teachers, nor do they recognize it as an objective that they themselves would favor.

Question #4: How would you describe yourself as a teacher? That is, What is your role as teacher in the classroom, what is the students' role? How would you organize the class with respect to leadership, control, discipline?

An attempt was made here to rate the description of the social system of each classroom as being either Traditionally Prescribed, Rationally Prescribed, or Constructed. In a Traditionally Prescribed classroom, behavior is justified by past norms; authority and standards are likely to be teacher dominated. In a Rationally Prescribed classroom, behavior is justified by some understood, logical, enlightened system; authority and standards function for the teacher and the student through the control of the logical system. In a constructed classroom, behavior is justified by an awareness of the possibility of the personal invention of new social situations; authority and standards are intrinsically determined by the teacher and the students. The classrooms were rated as follows:

Traditionally Prescribed	9
Rationally Prescribed	28
Constructed	3

It should be noted that further analysis of the teacher responses will probably reveal to what extent a classroom is bound to one social system, and to what extent classes are free to alternate between different social systems to meet different needs.

Question #5: What particular role do you see the laboratory playing in physics teaching?

Twenty-two of the teachers felt that the proper role of the laboratory was primarily to demonstrate concepts, laws, etc. Only eight teachers thought that the laboratory should be used for open-ended investigations. Fourteen of the teachers felt that explicit directions should be given to each student for each laboratory. Thirty-one teachers required a written report of each laboratory and twenty-seven of these provided the students with a lab report format that the student was expected to follow when writing. Thirty-one of the teachers stated that the students' laboratory work contributed significantly when final grades were determined. These figures seem consistent with the breakdown of classrooms given in Question #4.

Question #6: What factors in your school situation present difficulties to you as a physics teacher? That is, are there any constraints imposed by student level, by administration, by budgets or space which prevent or hinder you from doing some things you would like to do as a physics teacher but can't, or which force you to modify your approach from some more ideal way?

The following factors were mentioned by the teachers as their major constraints:

Number of Teachers	Constraint
19	Space
18	Schedule
14	Budget
12	Administration Policy
3	Equipment
2	Time, Varied Student Math Skills, Student Ability, External Examination, Parental Attitudes, Guidance Department Policies.
1	Extra Duties, Syllabus, Emphasis on Grades, Teacher Work Load, No Computer Facility.

Questions #7 and #8:

#7. What do you think the role of physics has been in the past in our culture and are there any real changes occurring in that role today?

#8. What do you think about the money being spent on scientific research today? Would you continue it if you could choose? Which projects might you continue to support and which would you definitely abandon?

Questions 7 and 8 were asked in succession as part of a single discussion. The teachers' comments were scored by the researchers according to the five factors listed below along with the results:

(a) Somewhere in the discussion, the teacher clearly indicates that he distinguishes science from technology in a meaningful way (26 teachers).

(b) The teacher indicates an overall positive affect about the "role of physics...in our culture" and about "the money being spent on scientific research" (31 teachers).

(c) The teacher expressly indicates a positive affect towards pure science (29 teachers).

(d) The teacher expressly indicates a positive affect towards technology (32 teachers).

(e) The teacher lists personal priorities for technological projects (28 teachers).

Question #9: How do you view scientific knowledge, in particular in the discipline of physics? How real are the current conceptions of the physical world? What do you expect will change in the future?

The responses to this question were complex and varied; there are no simple conclusions available at this time. The data is being explored in depth in an attempt to arrive at some knowledge about the teachers understanding of science.

A number of statements follow which were taken from the teachers' responses to question 9.

A common type of statement made by teachers is the following:

> "I believe that we already know a tremendous amount about how things work, and what they do, and I think that what we (i.e., physicists) are learning now is not a difference in ideas but a refinement of ideas."

Or a second teacher:

> "I think that our physical concepts today are good; they are strong, and I think that we are just going to refine them to get at more basic truths as we go along."

These statements, of course, are very naive as to the nature of physical knowledge and to the possibility of revolutions in scientific knowledge; they reflect a point of view about physics that was most popular about ninety years ago. An improved statement of the case, given by a third teacher is:

> "Many concepts are not exact enough, so, I suppose, it is going to be mainly a question of refining some every once in a while; but, then, there is always the possibility of some breakthrough when they (i.e., the physicists) come out with some new, fantastic idea."

This latter statement recognizes that it is also the role of the physicist to "come out with some new, fantastic idea;" i.e., to creat new physics knowledge, new principles and theories. Two roles for physicists have been suggested then, the first to "refine" existing physics knowledge, and the second to "create" new principles and theories. These distinctions are well known in the literature: the "refining " role could be associated with Kuhn's (1962) normal science or Schwab's (1962) stable enquiry: whereas, the role of creating new principles and theories could be associated with Kuhn's extraordinary science or Schwab's fluid enquiry. Robinson (1968) uses an even more descriptive terminology referring to the first type of role as completive scientific enquiry and the latter type of role as generative scientific enquiry.

A second, and related question that should be raised, even with these three brief quotations, is the status that the teachers give scientific knowledge, (e.g., the second teacher refers to "basic truths"). The status of knowledge is directly related to how it is produced, and certainly the status of physics knowledge should be given primary importance in an introductory physics classroom. Neither completive nor generative scientific enquiry leads to results which are compatible with "basic

truths" which have the status of certainties. Yet, the teacher's statement that follows was not untypical among the interviews:

> "Well, I do think that nature has given us a set of truths that we are trying to uncover. I feel that we are uncovering more of these truths as time goes on."

A teacher that expressed nearly this same point of view then ventured this quandary:

> "I think models are a good use to help people understand what you are talking about, but the only trouble with models is that there are usually discrepancies between the model and the real thing that very often leads to confusion."

Some more enlightened, sophisticated responses to Question 9 include the following:

> "The way that I try to approach teaching science is that it is not, certainly, absolute truth; it is provisional truth. These concepts that we use, then, like electrons and what not, are the best that we can do at describing certain things which we can't see directly, and the concepts seem to serve very well in figuring out what is going on in atoms. And, in that sense, they are very real to me... How are constructs connected with the original information? This is something philosophers and historians have gone around and round on. I would call it some sort of grey area. Personally, I don't think that there is any simple answer to the question. These constructs are, I think, undeniably man-made. They do not come directly from the real world so there is something that goes on in man's mind that generates these concepts, and we don't understand that fully."

And another teacher:

> "I don't see any concept in science as absolute or sacred. I think that that is the lesson that physicists have learned over the past 75 or 100 years. I think that now we understand that a concept is good as long as it works and will predict for us. And as soon as we find discrepancies, after a reasonable amount of time to let the concept right itself if it is possible, then probably we should take a whole new approach."

Or a final teacher:

> "I am trying to teach a concept of scientific thinking rather than just a whole body of scientific knowledge that is known today. My opinion of it is just model building, not necessarily the truth, not even necessarily approaching the truth. It's a lot of puzzle solving and it's a lot of trying to come up with some model that just fits the situation right and fits the observed phenomena; and if they come across a block, they eventually try a new model. This is what keeps science going."

III. PHYSICS CLASSROOMS

Introduction

In this study, the analysis of the characteristic ways in which the actual operations of teaching physics are performed is dependent upon information obtained from the perceptions and descriptions of the participants, and anecdotes and tape recordings of the classroom in action as collected by one of the research team members. The first of these methods draws upon the perceptions of the students in an attempt to determine what kinds and to what extent different activities occur in their physics classrooms. It also involves weekly record keeping by the teacher in terms of the approximate percentage of time per week devoted to various classroom activities. In addition, the teacher was asked to complete an extensive curriculum resources checklist which was designed to determine what curriculum materials were used.

Techniques Used to Determine the Teaching of Physics

Participant Contributions:	Other:
Teacher - Curriculum Resources Checklist Weekly Activity Summaries	Tape recordings Anecdotes
Student - Physics Teaching Opinionnaire Interview	Physics Laboratory - Observation Table

The description of classroom practices through the use of student perceptions has proven to be a valuable method of learning about various classroom activities. This method relies on the students' perception of the daily events in the classroom and their attitudes towards these events. There have been a number of attempts to describe the classroom activities with student questionnaires, but the work of Kochendorfer[3] has had the most influence on this study. For this study a set of questions about the physics classroom was prepared as an opinionnaire titled the "Physics Teaching Opinionnaire." This opinionnaire was administered to all of the students in each of the classes studied. Subsequently a random sample of five students from each class was chosen for individual in-depth interviews that probed more openly the students' perceptions and attitudes in terms of the categories used on the "Physics Teaching Opinionnaire."

Since our class research time was limited to one week per school, some method was required that would provide for a more complete picture of what takes place in the physics classroom over a longer period of time. A technique was used by Klopfer[4] where he asked teachers at the end of a

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[3]Leonard H. Kochendorfer, "The Development of a Student Checklist to Determine Classroom Teaching Practices in High School Biology," in Addison E. Lee (ed.), Research and Curriculum Development in Science Education, Austin Science Education Center, The University of Texas, 1968.

[4]L. E. Klopfer and W. W. Cooley, The Use of Case Histories in the Development of Student Understanding of Science and Scientists, USOE Contract 896, Cambridge, Mass., Harvard University, 1961.

term's work to estimate the approximate percentage of time devoted to various activities in their classrooms. This same technique was adopted for this study, but the teachers were given fifteen weekly activity summary forms and were requested to fill them out once or twice a week or daily, if possible. Eleven categories were selected as possible learning activities in the physics classroom. These categories were then given further scrutiny by the Project's advisory panel and, after some minor changes, determined to be adequate for the purposes of describing the activities of a physics classroom.

Twenty-two teachers cooperated in this effort (perhaps one of the most intrusive parts of the study) to describe the daily activities, objectives and materials used over a fairly long period of time. Of these twenty-two teachers, seventeen complied with the stipulated reporting procedures which would allow for a standardized method of summarizing the data.

Various components in the school situation (i.e., budgets, facilities and schedules), exerting different degrees of influence upon the physics program, have been elaborated on to some depth in the previous chapters. Understandably, these play an important role in determining the nature of the physics program offered, and one aspect of the teacher's role is in contending with these factors in his attempt to offer what he considers to be the ideal program. However, once budgets, facilities and schedules become established, the teacher must function within these limits. Our emphasis here will be concentrated then on two dimensions of teacher activity that take place within these limits. The two dimensions that are most central to the teaching act are the roles of curriculum creator and director of learning activities.

As a curriculum creator the teacher selects materials for the study of different subject matter topics according to the particular emphasis he wants to stress. Included in the materials the teacher could use are all of the various curriculum resources available as indicated in the following listing:

Written Materials

Textbooks:

- Various modern traditional (standard) texts
- National curriculum project texts: PSSC, Project Physics
- Library books
- Journals
- Programmed workbooks
- Teacher's writings
- Reprints
- Other references

Media

- Film and film loops (national curriculum project films)
- Film strips
- Tape recordings and records
- Video tapes
- E.T.V.

Laboratory Materials

Lab manuals: traditional, PSSC, PP
Lab equipment: traditional, PSSC, PP

Although budgetary considerations can be the limiting factor on which curriculum materials are actually in use rather than the teacher's ability to function as a curriculum creator, only seventeen percent of the teachers indicated that budgets were a constraint upon the type of program they were trying to offer. Therefore, it would seem as though the other thirty-five teachers had several degrees of freedom in purchasing materials for their program.

Curricular Interactions

The actual curriculums observed in the classrooms varied greatly from teacher to teacher throughout this study. Table 14 shows a breakdown of the sample according to the major text used by the pupils in each of the classes studied.

TABLE 14: CURRICULUM INTERACTIONS

Traditional (23)

7 "Pure" Traditional*
10 Traditional with PSSC Influence
6 Traditional with PSSC & PP Influence

PSSC (14)

7 "Pure" PSSC
4 PSSC with Traditional Influence
1 PSSC with PP Influence
2 PSSC with Traditional & PP Influence

PP (5)

4 "Pure" PP
1 PP with Some PSSC Influence

*A listing of major text titles and authors was given in Table 5.

Evidence indicates that in some schools the physics curriculum was limited to one major text and its accompanying materials. In such instances the program has been designated on Table 14 as "pure" Traditional, PSSC or PP. One of the aims here was to determine the degree of influence each of the national curriculum projects has had upon other curriculums. Therefore, reference to a traditional program as "pure" simply means there has not been any influence from the national projects and is not meant to suggest the strict coordination of text and lab manual by the same author.

Parts of the PSSC curriculum were found in sixteen of the traditional

curriculum classes and one Project Physics course. Project Physics curriculum materials were in operation to varying degrees in three PSSC classes and six traditional curriculum courses. To identify which curriculum materials were utilized, the teacher completed the Curriculum Resources Checklist (Appendix C). This is a very extensive listing of curriculum materials compiled from the materials of several traditional texts and lab manuals and the materials of the two national curriculum projects. The extent of interaction between the various curriculums was determined from the data on these checklists. At the lowest level of interaction the teacher was using a traditional text and ordering several of the PSSC films throughout the school year. The highest level of curriculum interaction was observed for a teacher of a traditional text who had incorporated both the PSSC and Project Physics lab manuals, PSSC films, and Project Physics film loops, transparencies and readers. A detailed summary of the curriculum interactions found in these classes is given in Table 15. In addition to the curriculum materials listed in Table 15, eighteen schools were in possession of the Science Study Series (9 traditional, 7 PSSC, 2 Project Physics schools), but only two schools indicated that these volumes were used as a regular part of the physics curriculum. In most of the schools this series was found in the school library, shelved under various sections and unrecognizable as a set of related titles comprising a series. In a couple of schools this series had been ordered by the school librarian and the physics teacher was unaware that the school possessed the series.

In so far as reading from sources other than the basic course text is concerned, one teacher made extensive use of Scientific American reprints and another teacher recommended readings in the Physics Teacher on an independent study basis. This finding is rather distressing in view of the Walberg study of Reading and Study Habits of High School Science Students, where it was found that even the elite students who take physics were in need of guidance in effective study methods. During interviews with the students, questions were asked about other techniques that their teacher used to help them learn physics. In most of the schools, except for the Project Physics schools and a few others that had highly integrated curriculums, the pupils were uninformed about related literature that could possibly enhance and broaden their study of physics.

Only in a couple of cases was evidence found indicating that the teacher was writing any original material other than self-styled laboratory write-up sheets, problem sheets and exam papers. In such cases the teacher was usually attempting to interpret a particular topic in physics or presenting historical or background information.

Classroom Activities

Much concern has been expressed in the field of education in recent years over the lack of knowledge about what actually happens in classrooms (Jackson, 1965; Schwab, 1969). In the present study an attempt has been made to collect information on the activities in operation in physics classrooms. Specifically the aims of the study in this respect were to:

1) determine the types of activities used in physics classrooms.

TABLE 15: DETAIL OF CURRICULUM INTERACTIONS

Number	Basic Text	Labs	Films	Film Loops	Demon-stration	Trans-parencies	Readers
7	T	T					
2	T	T	PSSC				
1	T	T	PSSC	PP			
2	T	T,PSSC					
6	T	T,PSSC	PSSC				
1	T	PSSC,PP					
1	T	PSSC,PP	PSSC	PP		PP	PP
1	T	T,PSSC,PP	PSSC				PP
1	T	T,PSSC,PP		PP	PP	PP	
1	T	T,PSSC,PP		PP			
7	PSSC	PSSC					
1	PSSC(T)*	PSSC					
3	PSSC	PSSC,T					
1	PSSC	PSSC	PSSC,PP	PP			
1	PSSC,T,PP	PSSC,T		PP			
1	PSSC	PSSC,T,PP		PP	PP	PP	
4	PP	PP		PP	PP	PP	PP
1	PP	PP,PSSC		PP	PP	PP	PP

*Inner City, traditional text for slow readers.

2) determine to what extent the respective activities are used.

3) describe variations that exist between teachers and interns of learning activity emphasis.

Table 16 is a summary of the data recorded by the teachers on the Weekly Activities Checklists. The mean values provide some indication of how physics teachers allot time to these respective activities. The high and low values are not from the same teacher in every case but represent the extremes reported for each category. For comparative reasons four teachers identified as A, B, C and D, who varied greatly in their use of the various learning activities, have been listed on the right side of the table.

The first four categories of classroom activities are highly teacher-centered. For the most part it can be seen that these activities comprise about half the classroom time. The distinctions between a teacher lecturing, discussing, or doing problems are not as clear at all times as would be desired, because in many cases the teacher demonstrates or does problems and discusses them at the same time. For this reason some of the teachers in the study expressed concern with the accuracy of the values they reported in these categories. Therefore, it may be more valid and useful to combine the first four categories to see how the teacher functions in the program. However, the values that were listed for problem-solving and demonstration can certainly be viewed as indicators of what emphasis the teacher felt he put on these activities. In the following discussion, reference to teacher-centered activity will mean the combination of the values reported for lecturing, discussions, problem-solving, and demonstrating.

Teacher-Centered Activities

A combination of Categories: 1, 2, 3 and 4

	% OF TIME			TEACHER			
	Lo	Mean	Hi	A	B	C	D
Lecture, Discussion, Problem, Demonstrations	25%	45	61	34%	61	25	50

When forty-five percent or almost one half of the class time is taken up by the teacher, then how is the remaining time used? On the average, ten percent of it is devoted to classroom evaluation (quizzes and tests), twelve percent by students working on problems, and twenty-two percent is accounted for by laboratory work. The other ten percent is distributed between student demonstrations (1%), A.V. (4%), and the category of "Other" (5%) which includes free time, independent study, review and test revision. A close examination of the variations in amount of time devoted to teacher-centered activities reveals some rather diverse differences in teaching styles. Teacher C indicates that he is at the center of class twenty-five percent of the time. Teacher A uses thirty-four percent of his time this way, while teachers B and D report sixty-one and fifty percent, respectively. In view of such variations, how do the teachers reporting low values for teacher-centered activity redistribute their class time to other learning activities? Teacher A has substantially increased the amount of lab time in his course to a value of forty-five percent as compared to the mean value

TABLE 16: WEEKLY ACTIVITIES

Activities	Percent of time per week devoted to respective activities			Differences in activity emphasis for four schools			
	Lo	Mean*	Hi	A	B	C	D
1. Lecture	5	16	41	15	41	5	20
2. Discussion	8	17	27	18	12	14	15
3. Problems by Teacher	0	8	18	0	5	6	10
4. Demonstrations by Teacher	0	5	14	1	3	0	5
5. Laboratory	11	22	45	45	13	11	15
6. Demonstrations by Student	0	1	4	0	1	2	4
7. Problem by Student	0	12	22	0	6	18	10
8. Films and Other AV	0	4	11	8	5	0	3
9. Tests and Quizzes	5	10	18	5	15	11	13
10. Other	0	5	32	7	0	32	4
		100%		99%	101	99	99

*17 schools reporting for an average of 12 weeks per school

of twenty-two percent. He also indicates that seven percent of the time is used as student optional activity which he reports as "other" types of activities. In addition, he has increased the amount of time allotted for A.V. use and reduced the amount of time normally taken up by evaluation type of activities. Teacher C allows thirty-two percent of the time in his class for student independent study and eighteen percent for student problem work while retaining twenty-five percent for teacher-centered activities. The situation in this class is rather unique in that this teacher directs his class in a fairly traditional manner for a few weeks and then alternates with a unit of work he designates as independent study, although it is really guided independent study. Guided because he retains most of the control of what will be studied but allows the students to set their own pace and to somewhat vary the emphasis they place on the materials being studied; that is, some of the students might do more experiments or problems while others explore different readings. During the thirteen weeks in which this teacher kept records of his classroom activities, two independent study units were initiated that accounted for four of the thirteen weeks. In contrast to the style of teacher C, teacher B concentrates on presenting lectures to the class interspersed with some discussion and a few teacher demonstrations and problem examples. And teacher D operates a fairly typical program with little variation from the mean values for each activity as reported by all teachers combined. Thus far the percentage time allotments for the different learning activities have been discussed in terms of their frequency of occurrence. The next step will be to determine how these activities are ordered over a period of time and to explore to some extent the quality of the activities. Currently, further analysis is underway at Teachers College, Columbia University, analyzing individual classroom lesson presentations and an attempt is being made to identify the sequencing patterns different teachers use in the ordering of learning activities.

Student Interviews

With such wide variations exhibited between teachers in the use of different learning activities, it would be useful to compare the teachers according to the type of curriculum in operation. Regretfully, all of the teachers did not complete the weekly summaries; therefore, it is impossible to determine which activities were emphasized and to what extent variations exist across the different curriculums. However, the Physics Teaching Opinionnaire was administered and students interviewed in all of the classes, so for comparative purposes the information obtained from these students will be grouped according to the major text the students used and for all students combined together.

In view of the different teaching styles that are suggested in Table 16, it appears that one of the primary differences in the type of learning activity emphasized is closely related to the authority structure in the classroom. When teachers A and C allot almost half of their class time to optional and independent studies, they are allowing much of the control and pacing responsibilities of the classroom time management to be assumed by the student. In contrast, almost twice as much time is under the teacher's control for teachers B and D. When the students were asked to describe the normal scene in their classroom and whether the teacher allowed for student self-direction or was in direct control most of the time, the following responses were given:

Teacher Control

Curriculum	Direct	?	Indirect
Modern Trad.	76%	4%	20%
PSSC	62	-	38
Trad. Combination	54	4	43
Project Physics	9	4	87
All Schools	60	3	37

In response to a question concerned with the activeness or passiveness of the role of students in the normal operations of the physics classroom the students answered this way:

Student Role

Curriculum	Active	?	Passive
Modern Trad.	15%	8%	77%
PSSC	56	2	42
Trad. Combination	60	8	32
Project Physics	83	-	17
All Schools	43	5	52

Substantial differences can be seen between the responses of students in the respective curriculum programs but this is certainly to be expected since each of the programs is associated with particular conceptual approaches both in terms of pedagogies to be employed and the nature of the curriculum content specified. The obvious differences in teacher control exist between the Project Physics teachers and the traditional curriculum teachers. Nine percent of the Project Physics students perceive their teachers to be in direct control compared to 76% for the traditional curriculum schools. In a like manner, 83% of the Project Physics students indicate that the student plays an active self-directed role in this classroom in contrast to only 15% for the traditional class students. A little over half the students in the classes using traditional combined curriculums report their teachers to be in control while simultaneously sixty percent of the students see themselves as having an active role in classroom operations. Two possible interpretations can be given to this near 50-50 split. One is that the teachers of these classrooms use different teaching styles. The other is that the teacher may vary his teaching approach in a manner similar to teacher C who incorporated independent study units in his program from time to time, which thereby suggests both teacher control and active self-directed student involvement. The fairly high percentage of 56% of the students in

the PSSC classes who reported active student involvement indicates that something is different in these classes when they are compared to the traditional curriculum classroom where only 15% of the students reported having an active role. To understand these differences more completely, the students' responses to the Physics Teaching Opinionnaire will be considered in the next section.

Physics Teaching Opinionnaire

Several aspects of the teacher's role and influence in the physics classroom were explored in the Physics Teaching Opinionnaire. Three subtests of six questions each focused on the classroom in general in terms of the teaching strategies used by the teacher, the classroom social system and the kind of science being studied in the course. The objectives of the other two subtests on the opinionnaire were to determine what role the laboratory played in the teaching of physics and what criteria the teacher used in evaluating the pupil's work.

A. Teaching Strategies

The subtest of teaching strategies, Table 17, is composed of a set of questions designed to determine the extent to which some teaching techniques are used in physics classrooms. The first five questions are concerned with the type of teacher control and nature of teacher-student interactions. Question one asks the students about how much of the class time is spent listening to the teacher lecture or demonstrating. The Project Physics students report the least amount of teacher lecturing, forty percent, which is in agreement with their responses in the interview that students in these classes have a very active role. The students in the integrated curriculum, PSSC and traditional classes all report about equal amounts of this type of teacher-centered activity: sixty-one, fifty-six, and fifty-eight percent, respectively. When asked if the objectives for their classes are well explained and known by the class, the students' responses were in close agreement with the results found by matching the students perception of the teacher's objectives as reported in section 2. The students in the integrated curriculum classes did rather poorly when asked to state their teacher's objectives, but seventy-three percent of them responded strongly in the affirmative that the objectives for their course are well explained. One possible interpretation for this inconsistency is that it was only in these classes that learning contracts were used by the teachers. These contracts specify precisely what the student must accomplish to attain the grade he chooses in terms of problems, readings, labs and reports. For this reason the students in these classes may be perceiving these contracts as lists of objectives and reporting a high value of understanding the objectives for the course due to the explicitness of the learning contracts. However, when it came to matching the overall objectives of the teachers, these students failed to interpret their teachers correctly.

Item numbers three and four of this subtest are concerned with the degree of teacher control in the classroom setting, as conveyed by his regulations and rules and by the presence or absence of situations where the student must make decisions on his own without the teacher's directions. The students studying from the integrated and traditional curriculums report higher percentages of rules and regulations in their classrooms than do the students of the Project Physics and PSSC classes. One interpretation of

TABLE 17: TEACHING STRATEGIES

		RESPONSES %	
	Curriculums*	Always/Often	Sometimes/ Never
Item 1			
Much of the class period is spent listening to the teacher lecturing or demonstrating.	Modern Trad.	58	42
	PSSC	56	44
	Trad. Comb.	61	38
	PP	40	60
	All	55	44
Item 2			
The objectives of the course are well explained and known to the class.	Modern Trad.	66	35
	PSSC	60	40
	Trad. Comb.	73	27
	PP	53	47
	All	64	36
Item 3			
Our class is rather informal with not very many regulations and rules.	Modern Trad.	66	34
	PSSC	79	22
	Trad. Comb.	63	38
	PP	76	25
	All	72	29
Item 4			
Students determine the method or procedure for a laboratory experiment.	Modern Trad.	17	84
	PSSC	19	81
	Trad. Comb.	16	84
	PP	19	81
	All	18	83
Item 5			
The teacher encourages us to find out things for ourselves instead of asking someone else.	Modern Trad.	78	23
	PSSC	81	20
	Trad. Comb.	75	25
	PP	79	21
	All	78	22
Item 6			
Films shown in class are well integrated with class topics through discussion and questions.	Modern Trad.	43	57
	PSSC	44	56
	Trad. Comb.	53	47
	PP	62	38
	All	47	53

*The number of responding students in each category is as follows: Modern Traditional - 375; PSSC - 280; Traditional Combination - 116; PP - 108; Total - 879.

this difference is that the independent and optional study activities of the Project Physics program eliminate the normal classroom rules and regulations that are required to maintain and contain students in one position for an entire period. In the case of the PSSC classes where the students have indicated that the teacher lectures and is in direct control, they still report their classes to be fairly informal with not many rules and regulations. When the data regarding student freedom in determining the method or procedure for a laboratory experiment is considered as occurring always, often or sometimes versus never, further insight into the operations of the different programs is provided. Seventy-three percent of the students in the integrated and Project Physics curriculum report that this activity does occur at some time as compared to 56% and 54% of the students answering in the same way in the traditional and PSSC classrooms respectively.

Item 4		Student Responses*	
	Curriculum	Always/Often	Sometimes/Never
Students determine the method or procedure for a laboratory experiment	Modern Trad.	56%	45%
	PSSC	54	46
	Trad. Comb.	73	27
	PP	73	27
	All	61	41

*In some cases it is useful to look at the students' responses in terms of the activity ever occuring versus never occuring. All of the items on the Physics Teaching Opinionnaire have been analyzed this way but only those yielding additional information to the Always/Often versus Sometimes/Never analysis will be reported.

About seventy-five to eighty percent of the students in all four types of curriculum classes responded that their teachers encouraged them to find things out for themselves, which is interesting in light of differences in teacher control and student role reported earlier. In answer to a question on how the teacher integrates film with class topics, only 43% and 44% of the students in traditional and PSSC classes said that the films shown in class were well integrated with class topics through discussion. While at the same time 62% and 53% of the students in Project Physics and traditional combination (integrative) curriculum classroooms respectively replied that the films were well integrated. With the extensive use of single concept film loops in the Project Physics schools and use of these loops in the integrated curriculum classes, it is understandable how these students see films, e.g., film loops, as being an integral part of their curriculum. With regard to the regular use of PSSC or other films from film order houses or A.V. centers, it would be difficult to say that the teachers of Project Physics or the integrated curriculums had done any better in ordering and scheduling films than any of the other schools. The effective integration of films into the physics curriculum seems to be dependent upon two factors. One is the degree of organization and planning exhibited by the physics teacher. In several instances teachers said they were forced to order films a year in advance if they wanted to use them in connection with topics being presented in class. The other factor is closely related to the problem

of ordering films. In one or two school districts visited, the administrations had pooled their resources with other districts creating a central film library. The teachers in these districts were found to have much more ready access to films than the teachers who were forced to order from a film rental agency.

B. The Classroom Social System

Closely related to the questions on teaching strategies are the subtest questions in Table 18 that ask the student about how students and teachers interact with one another and what constraints are imposed upon these interactions. The objective of these subtest questions was to probe into some aspects of classroom life that exemplify these interactions.

Items one and two are posed specifically to get at the students' perceptions of how the teacher interacts with them. It is assumed that the teacher who is always the group leader has a different attitude towards what students are capable of doing on their own than does the teacher whose styles of interaction are less dominative. The students in the Project Physics and PSSC curriculums gave similar responses, 49% and 47%, respectively, indicating that their teacher was generally more of a participant in class than a leader. This response by the PSSC students suggest that their teachers are less authoritarian than indicated by the information they gave in the interview where 62% said that their teacher was in direct control of the situation. However, only 9% of the students interviewed from the Project Physics schools said their teachers were in direct control but now in response to this question, only 49% see their teacher more as a participant than as a leader.

Items three, four, and five pertain to the orderliness and control of the classroom. In response to the question about their classroom being a normally quiet and orderly place where everybody knows what will happen next, fifty-three percent of the students in the Traditional Combination Classrooms report this to be the case; while only forty-two, forty and thirty-three percent of the students, respectively, from the Modern Traditional, PSSC, and Project Physics classrooms answered this way. The low value for the Project Physics classes suggests that these classes are less orderly and directed as might be expected when there is active student involvement. However, in the schools where the teacher is said to be in control, one would expect higher values of agreement than were reported. The students from the integrated curriculum classes indicate that their classes are the most orderly and directed, which again might be related to the use of learning contracts in these classes and the subsequent clarification of exactly what is expected of the student. These same students report the lowest value of agreement, five percent, with the statement that their class has no direction or purpose evident. Seventeen percent of the Project Physics strongly agree with this statement while ten and eight percent of the students from the Modern Traditional and PSSC classes, respectively, concur. In terms of punishments for certain types of rule-breaking in the classroom, thirty-nine percent of the Project Physics students reported they were usually aware of how their classroom operates in this respect. In contrast, it was the group of students in the integrated curriculum classes that previously reported their classes to be the most orderly that now report the lowest value, twenty-two percent, for awareness of punishments for certain types of rule-breaking. The PSSC students also report a

TABLE 18: CLASSROOM SOCIAL SYSTEM

		RESPONSES %	
	Curriculums	Always/Often	Sometimes/ Never
Item 1			
The teacher joins the class more as a participant than as a leader during physics class periods.	Modern Trad.	42	57
	PSSC	47	53
	Trad. Comb.	31	69
	PP	49	52
	All	43	57
Item 2			
The teacher is careful to hold back criticism at times when feelings of students might be unnecessarily hurt.	Modern Trad.	61	39
	PSSC	65	35
	Trad. Comb.	68	32
	PP	64	36
	All	64	36
Item 3			
Our classroom normally is a quiet and orderly place where everybody knows what will happen next.	Modern Trad.	42	57
	PSSC	40	60
	Trad. Comb.	53	47
	PP	33	67
	All	42	58
Item 4			
Our classroom is a noisy and active place with no direction or purpose evident.	Modern Trad.	10	90
	PSSC	8	93
	Trad. Comb.	5	95
	PP	17	83
	All	9	91
Item 5			
There are punishments for certain types of rulebreaking of which all the class is aware.	Modern Trad.	31	69
	PSSC	24	77
	Trad. Comb.	22	78
	PP	39	60
	All	28	72
Item 6			
I have an assigned partner or group I must work with in laboratory periods.	Modern Trad.	53	47
	PSSC	30	70
	Trad. Comb.	30	70
	PP	25	75
	All	39	61

low value of twenty-four percent having this kind of awareness, while thirty-one percent of the traditional students answer this way.

Another dimension of the social system of the classroom involves the nature of student-student interactions. One way the teacher effects student-student interactions is by allowing students to choose their own lab partners. This was the case in all the classes except those using the Modern Traditional curriculums, where 53% of the students in these classes indicated that their teacher always or often assigned partners or groups.

C. Subtest on the Nature of Science

What kind of science is taught in the physics classroom is probably one of the most important questions to be considered in a study of physics teaching. The work of J. J. Schwab,[5] particularly The Teaching of Science as Enquiry, has greatly influenced the type of question asked in the subtest on the nature of science. Schwab speaks of the "enquiring classroom" in two respects. First he suggests its materials should exhibit science as enquiry, and secondly students should be led to inquire into these materials. The primary objective of this subtest of questions was to find out to what extent the concept of "enquiring classroom" had been implemented in physics classrooms since 1961 when Schwab elaborated on this approach to teaching.

The first three items in this subtest (see Table 19) focuses on the emphasis given in class discussions with regard to the kinds of problems faced by scientists, the nature of the evidence that is behind the statements in textbooks, and questions of scientific validity. Item number one fails to discriminate between the four curriculums except for a few percentage points difference. Items two and three solicited more positive responses from the PSSC students than from any of the other curriculums. In fact, only 58% of the Project Physics students reported questions from the teacher about the evidence that is behind statements in their textbooks as an always-often experience in their class as compared with 73% of the students in the PSSC classes. In terms of discussions about the validity of the evidence that is behind a scientist's conclusions, about half of the students from each of the curriculums reported this to be a fairly frequent event with the PSSC students reporting it to occur slightly more frequently than the students from the Modern Traditional and Project Physics classes.

Item number four pertains to the use of materials that exhibit science as enquiry. For this reason the students were asked if they read any original scientific writings either current or historical. Students from the Project Physics and Integrative curriculum classrooms responded significantly more positively to the always-often occurrence of this experience than did students from either of the other two curriculums. When the data is categorized according to whether the activity ever or never occurs, the following results are found (see page 39):

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5 Joseph J. Schwab, "The Teaching of Science as Enquiry," in The Teaching of Science, Joseph J. Schwab and Paul F. Brandwein (eds.), Harvard University Press, Cambridge, Mass., 1962.

TABLE 19: NATURE OF SCIENCE

		RESPONSES %	
	Curriculum	Always/Often	Sometimes/ Never
Item 1			
Our class discusses the problems faced by scientists in the discovery of a scientific principle.	Modern Trad.	22	78
	PSSC	27	72
	Trad. Comb.	24	76
	PP	29	71
	All	25	75
Item 2			
My teacher asks questions that cause us to think about the evidence that is behind statements that are made in the textbook.	Modern Trad.	65	35
	PSSC	73	27
	Trad. Comb.	65	35
	PP	58	42
	All	67	33
Item 3			
Our class discusses the validity of the evidence that is behind a scientist's conclusions.	Modern Trad.	45	55
	PSSC	55	46
	Trad. Comb.	51	48
	PP	45	55
	All	49	51
Item 4			
Students read the original writings of current or historical scientists as class work.	Modern Trad.	5	95
	PSSC	5	95
	Trad. Comb.	18	82
	PP	18	83
	All	9	92
Item 5			
Experiencing the difficulty of acquiring data in the laboratory is an interesting and a valuable aspect of learning about physics in this class.	Modern Trad.	62	38
	PSSC	69	31
	Trad. Comb.	70	29
	PP	68	32
	All	66	34
Item 6			
Our class experiences what physicists do and how they do it rather than reading about the resulting principles of physics.	Modern Trad.	43	57
	PSSC	51	49
	Trad. Comb.	48	53
	PP	52	48
	All	48	52

Item 4		Student Responses	
	Curriculum	Always/Often	Sometimes/Never
Students read the original writings of current or historical scientists as class work.	Modern Trad.	29%	72%
	PSSC	23	77
	Trad. Comb.	45	55
	PP	67	34
	All	34	67

The emphasis the Project Physics curriculum put on the historical developments in physics would seem to have had quite an influence upon materials read by high school physics students as evidenced by their responses to this question about reading original writings. The influence of these materials in the integrative curriculum classes is also indicated here in terms of those students' responses.

The last two items in this subtest were asked to determine whether the students felt their laboratory and class experiences were related to the kinds of work physicists are involved with, i.e., in terms of the problem of collecting data and experiencing what physicists do. The students responses here do not differ greatly among curriculums, although the traditional students consistently reported lower percentages of these activities than do the students of the other curriculums. Overall, the experience of having difficulties of acquiring data in the laboratory is seen by about two-thirds of the students as being an always-often activity. The students are in less agreement about how much they experience what physicists do rather than reading about the principles of physics. Here, only about one half the students say they do experience what physicists do.

D. Laboratory

The objective of the subtest of questions on the laboratory (see Table 20) was to determine how the laboratory is used in the teaching of physics. In particular, questions about the frequency of laboratory experience, introduction of lab work, purposes, teachers' roles in the laboratory, and the results of lab work were asked.

Item one asked the students about the regularity of lab work in their course. About 75% of the students in all of the classes reported this to be an always-often type of activity. Students studying from the Project Physics and Integrative curriculum reported a few percentage points above the average, and students studying from the PSSC and Modern Traditional curriculums reported a few percentage points below the mean. However, even when the data is considered from the perspective of occurring versus never occurring, none of the curriculums appear to be any more experimentally oriented than the others.

Knowing the results of a laboratory before doing the experiment suggests an illustrative role for the laboratory rather than an encounter with raw phenomena. Schwab notes that there are two differences between the dogmatic and enquiring uses of the laboratory. The first of these is that the laboratory work would proceed rather than follow the classroom treatment of a topic, and the second difference is that use of the laboratory

for demonstrative purposes be subordinated to the purpose of providing tangible experiences with the kinds of problems scientists deal with and the difficulty of acquiring data. Difficulty in acquiring data, not in the sense of trying to be precise in proving that $g=9.8$ m/sec^2, but in determining what data are needed for the solution of a scientific problem. These experiences, then, cease to be situations where the student is told what to do and what to expect.

Item two asked the students if they have an idea of what the results will be from an experiment before they do it. Overall the students are fairly evenly divided in terms of whether they regularly know these results before the experiment or not. Ten percent of the PSSC students say they never know the results beforehand compared to five percent of the students answering "never" in the Integrative curriculum classes and eight and seven percent in the Modern Traditional and Project Physics classes. In terms of this being a fairly frequent occurrence, the students in the Modern Traditional and Project Physics classes report the highest value, 61%, as compared to the value of fifty percent for the PSSC students and fifty-three for the Integrative classes.

When the students were asked questions about their laboratory experiences during the student interviews, their responses were consistent with those reported by the entire classes on the Physics Teacher Opinionnaire. The PSSC students continued to report substantially higher frequency of occurrence of enquiry types of activities when compared to the other curriculums except in the use of controlling work sheets, where the Modern Traditional curriculum students also reported a lower frequency of use, 58% versus 60% of the students, respectively, indicating these worksheets are used in their laboratories. This compares to values of 100% and 91% reported by the Traditional Combination and Project Physics curriculum students for the use of controlling worksheets in their laboratories. The summary of these interview responses is as follows:

		RESPONSES %		
Item 1	Curriculum	Yes	Maybe	No
Are experiments used for demonstration purposes in your class?	Modern Trad.	86%	5%	9%
	PSSC	77	9	14
	Trad. Comb.	92	4	4
	PP	95	5	0
	All	85	6	9
Item 2				
Do you have enquiring type of laboratory experiences confronting raw phenomena where the problem, as well as the method and answer, are left open for the student?	Modern Trad.	30	8	62
	PSSC	50	9	41
	Trad. Comb.	17	22	61
	PP	26	21	53
	All	36	12	52
Item 3				
Are your laboratory experiences structured through the use of worksheets or lab manuals?	Modern Trad.	60	1	39
	PSSC	58	3	39
	Trad. Comb.	100	0	0
	PP	91	0	9
	All	68	2	30

TABLE 20: LABORATORY

		RESPONSES %	
	Curriculum	Always/Often	Sometimes/ Never
Item 1			
Lab experiments are a regular weekly activity in this course.	Modern Trad.	71	28
	PSSC	73	28
	Trad. Comb.	81	20
	PP	77	23
	All	74	26
Item 2			
Before we do a laboratory experiment we have an idea of what the results will be.	Modern Trad.	61	39
	PSSC	50	51
	Trad. Comb.	53	47
	PP	61	38
	All	56	54
Item 3			
Lab experiments prove what we have already learned.	Modern Trad.	55	44
	PSSC	38	62
	Trad. Comb.	54	46
	PP	56	44
	All	50	50
Item 4			
Our laboratory work results in unresolved debates about concepts, methods of interpretations.	Modern Trad.	9	90
	PSSC	17	84
	Trad. Comb.	5	94
	PP	6	94
	All	11	90
Item 5			
Our teacher usually assists us in the lab by answering our questions with other questions rather than direct answers.	Modern Trad.	50	51
	PSSC	63	38
	Trad. Comb.	46	54
	PP	36	64
	All	52	49
Item 6			
We have free lab periods when we can do whatever interests us, i.e., repeat previous experiments, design a new experiment, or perform some other experiment.	Modern Trad.	18	82
	PSSC	27	73
	Trad. Comb.	30	70
	PP	60	40
	All	27	73

Subtest items three and four deal with the results of laboratory work. If the laboratory work gives results that were expected, it functions primarily as an illustrative experience. However, if the problem and circumstances involved in collecting data for solving the problem are emphasized to a greater extent than the conclusions, the laboratory functions more as an experience of enquiry. Just a little over half of the students in three of the different type of classes, excluding PSSC, reported their lab experiments to always-often prove what they have already learned. Only 38% of the students in the PSSC classes reported this to frequently be the case. While 12% of the PSSC students reported this to never happen, 8, 3 and 1 percent of the students, respectively, in the Modern Traditional, Integrative and Project Physics curriculums gave this same answer. In terms of laboratory work resulting in unresolved debates; 17% of the PSSC students say this happens frequently compared to 9%, 5% and 6% of the students in the Modern Traditional, Integrative and Project Physics classes.

Teacher control and interaction with students in the laboratory are the primary consideration in items five and six on this subtest. Item five was formulated to find out how the teacher interacts with the students in the lab. Does he always tell the student what to do next and how to do it or does he indirectly prompt the student to arrive at his own answers? The students in the PSSC classes reported more frequently that their teacher's interaction with them is indirect than did the students in the other curriculums. About half the students in the Modern Traditional and Integrative curriculum classes see their teacher interacting with them this way on a regular basis. Only 36% of the students in the Project Physics classes see this happening; 63% of the PSSC students do.

Item six asks the student if different kinds of opportunities are provided for him to explore his own interests in the laboratory in much the same way scientists do. Sixty percent of the students in the Project Physics classes reported that this kind of opportunity is frequently provided but only eighteen percent of the Modern Traditional curriculum students reported having this experience in any regular sense. According to the student responses, the Integrative and PSSC curriculum classrooms are slightly more permissive than the Modern Traditional classrooms, but not to the extent reported by the Project Physics students.

E. Evaluation

The extent to which a teacher emphasizes certain aspects of physics in his evaluation procedures may be the most valid indicator of his objectives in teaching physics. To emphasize certain aspects of physics over others implies that the points emphasized are the ones the teacher considers to be the most important components in the study of physics. Accordingly, the type of test questions he asks the student will reflect those aspects of physics he has emphasized. The kind of content knowledge required to answer the test questions will be a strong factor in determining what and how the student prepares his studies. This is particularly true of the extremely grade-conscious students who, after one or two tests, are likely to be very aware of what the teacher expects from them. To determine what aspects of physics were emphasized by the physics teachers on their tests, several questions were formulated. These were designed to explore the

type of questions used - memory or interpretation, how much mathematical ability was emphasized, whether laboratory work was evaluated, and how valid the test grades were in terms of what the student felt he understood in physics.

Item one (see Table 21) asked the students about the frequency of memory or knowledge of information type of questions on their tests. The students in all of the curriculums answered rather consistently, with about twenty percent reporting this type of question to be the most frequent type found on their tests. Overall 43% of the students said this kind of question was never the most important one on their tests. For the type of question in item two, i.e., interpretation questions, the students in both the PSSC and Project Physics curriculums reported more frequently these types of questions to be on their tests than did students in the other curriculums.

Regarding the emphasis upon mathematics in physics tests, 76% of the students in the Integrative curriculum classes and 71% in the Project Physics classes reported that questions requiring verbal as well as mathematical understandings are on their test frequently. Sixty-nine percent of the students in the Modern Traditional classes and 64% of the PSSC students experienced the same type of questions on a regular basis. When asked if the physics test really measured mathematical ability rather than understanding of physics, all of the students answered fairly consistently. The value of 28% for all schools combined is representative for the always-often frequency of occurrences of interpretative type questions on their physics tests, but it should also be noted that about 20% of all students in each of the curriculums reported that they never had these types of questions on their tests.

With respect to physics tests including questions based on things learned in the laboratory, the students from each of the different curriculums responded in much the same way. Roughly about two-thirds said these kinds of questions appeared regularly. However, close examination of the student responses reveals that 10% of the Modern Traditional class students said their tests never contained questions of this type, while only 6% of the PSSC and Project Physics students and 2% of the Integrative curriculum class students replied in a like manner.

Do the physics students feel that their test grades reflect their understanding of physics? Less than half of the students in the PSSC, Project Physics and Traditional Combination classes say this is frequently the case and only slightly over half the students in the Modern Traditional classes concur with this statement.

TABLE 21: EVALUATION

		RESPONSES %	
	Curriculum	Always/Often	Sometimes/ Never
Item 1:			
Questions requiring us to state memorized formulas, laws, and theories are the most important ones on our tests.	Modern Trad.	21	79
	PSSC	17	84
	Trad. Comb.	20	80
	PP	23	77
	All	20	80
Item 2:			
Questions requiring us to draw conclusions from new data are asked on the tests.	Modern Trad.	33	67
	PSSC	42	58
	Trad. Comb.	36	64
	PP	42	59
	All	38	61
Item 3:			
Questions requiring verbal understanding as well as mathematical understanding are asked on the tests.	Modern Trad.	69	31
	PSSC	64	35
	Trad. Comb.	76	24
	PP	71	29
	All	69	31
Item 4:			
Physics tests really measure mathematical ability rather than understanding of physics.	Modern Trad.	30	70
	PSSC	25	75
	Trad. Comb.	24	76
	PP	31	69
	All	38	73
Item 5:			
Our tests include questions based on things we have learned in the laboratory.	Modern Trad.	60	40
	PSSC	64	36
	Trad. Comb.	66	35
	PP	65	35
	All	63	37
Item 6:			
The grades that I receive on my physics tests adequately reflect my understanding physics as a science.	Modern Trad.	53	47
	PSSC	43	57
	Trad. Comb.	47	53
	PP	44	56
	All	48	52

IV. THE STUDENTS

Physics Students Opinions Towards Science

Two main techniques were used to assess the attitudes of students in physics classes towards science (physics), science teaching, and science careers. In the Science Opinionnaire attention was focused upon five major categories of questions with multiple items under each. The categories used were very much influenced by current ferment regarding science. Often one hears that science is responsible for environmental problems or, worse, for a general "dehumanizing" influence in our culture.

In the following discussion of the results of the opinionnaire each category is identified and items within it producing significant responses are reproduced. Although four levels of response (strongly agree, agree, disagree and strongly disagree) were used, they are here collapsed into percentages of students in agreement, or in disagreement.

		Agree (%)	Disagree (%)
I.	Is Science Responsible for Today's Problems?		
	1. Science does not cause problems, the misuse of science does.	84	16
	2. Industrial profits, not science, are responsible for the pollution problem.	61	40
	3. Modern science is incapable of solving today's problems.	16	84
	4. The world would have been better off without some of the recent products of science.	48	51
II.	Could We Do Without Science?		
	1. It might be well to retard scientific activity for a time.	13	87
	2. Research in some fields should be given much more support.	96	4
III.	Should Scientists Care About the Consequences of Their Work?		
	1. A good scientist considers the consequences of his professional activity.	88	12
	2. A scientist ought to be free to do whatever experimental work he feels is important.	60	40

		Agree (%)	Disagree (%)
3.	Regardless of how the results of science are used, the scientist himself must share a major part of the responsibility.	73	27
4.	Some kinds of experimental work should be prohibited.	67	32
IV.	Do Students Have a Clear Picture of Science as a Profession?		
1.	Few professions offer opportunities superior to those a scientist might encounter.	43	57
2.	Much of scientific work is dull routine.	42	58
3.	Secrecy is an important positive influence upon American science today.	27	72
V.	Does Scientific Work Attract or Repel Students?		
1.	A scientific career offers a chance to do something really worthwhile.	91	9
2.	The rewards of a scientific career would not repay the effort involved.	17	83
3.	Scientific work is usually pretty far removed from everyday reality.	19	81
4.	Only a small percentage of the population could qualify to become scientists.	55	45
5.	I would like to become a scientist.	49	51

With a few exceptions, the overwhelming picture of science portrayed by these results is very positive and very supportive. In Category I, science is not seen as responsible for current ills, but is viewed as having been misapplied in some way and as certainly capable of contributing to solutions. Given that the world is viewed as better off without some of the recent products of science, in this context it would appear that science and technology are being confused.

Category II responses clearly indicate an enthusiasm for continued research support. However in Category III there is beginning to be expressed some concern for dictating priorities for scientists. This does seem to fit in with current social concerns for directing science through selective funding, a process that an appreciable number of physics students in high school apparently support.

Categories IV and V tend to be a more realistic appraisal of science as a profession than one normally expects from the population at large. No doubt some of the changes in attitude and information in this regard reflect the recent changes in employment patterns in science. Students are suddenly aware that science, too, is affected by economic woes. There is no guarantee of a glamorous future simply by choosing science. A statistic supportive of the generally optimistic appraisal of science is that 83% of high school physics students feel that the rewards of a scientific career would repay the effort involved. On the other hand, only 49% would like to become scientists.

A preliminary attempt was made to compare the responses of social studies students with physics students. This was difficult because of the fact that many social studies students who had taken physics, were taking it concurrently, or had taken sufficient other courses in science to confound the issue. However a small sample of about 470 social studies students was compared to the overall physics student responses (1120 students). The following items from the opinionnaire were the only ones that showed a significant difference (X^2 at 0.05 level) between the groups.

			A	D
1.	Science depends on free and open communication.	PHY.	88.1	11.9
		S.S.	79.1	20.9
			A	D
2.	Secrecy is an important positive influence on American science today.	PHY.	27.1	72.8
		S.S.	41.5	58.5
			A	D
3.	The frontiers of science are exhausted.	PHY.	5.	95.
		S.S.	8.2	91.8
			A	D
4.	It might be well to retard scientific activity for a time.	PHY.	13.2	86.8
		S.S.	21.	79.
			A	D
5.	The rewards of a scientific career would not repay the effort involved.	PHY.	18.8	83.2
		S.S.	24.4	75.6
			A	D
6.	A scientist ought to be free to do whatever experimental work he feels is important.	PHY.	60.3	39.7
		S.S.	44.5	55.5
			A	D
7.	I would like to become a scientist.	PHY.	49.5	50.6
		S.S.	25.1	74.9

The interview schedule used with five randomly selected students out of each class studied (a total of 210 interviews) was set up to do an in depth check of some of the more broadly collected data. It was hoped that clearer opinions could be gotten in this way and that perhaps some of the meaning of the mass response to the paper and pencil instruments could be better ascertained.

Analysis of the Student Interviews

Science Attitudes

The students' responses to the first question in the interview: "What comes to mind when you hear or see the word 'science'?" were gathered and categorized. Only the statements made by the students before further intervention by the interviewer were listed. There are more statements than students, because some (but not all) incorporated more than one thought or concept into their response.

Category 1. The Fields of Science

1a. Science as Subject Matter of Field of Specialization. Some students simply named one or more of the sciences, sometimes including mathematics, and left it at that. Others elaborated or mentioned additional ideas that occurred to them. A tally of the fields mentioned follows:

Subject	Number of times mentioned
Chemistry	35
Biology	24
Physics	23
Mathematics	6
Earth Science	4
Astronomy	2
Life Science, Oceanography, Geology and Zoology	1 each

Three general statements appeared: the fields of science; the subjects; and different kinds of science.

1b. Specific References to School or Education. Seventeen students made specific reference to school or education. These ranged from "Science is what we learn in school" and "Science is the class I'm in" to "Science is a different kind of subject you have to think about" and "It is a chance to advance my education."

1c. Science as a Career. Seven students responded by referring to career choices. Unfortunately only three of these related to actual sciences; one each to chemistry and biology, and one to a combination of biology and zoology. Three others mentioned either electricity or electronics, and a final vote was cast for forestry. (This does not mean that only seven of the students interviewed are planning such careers; just that the first thoughts on science did not usually relate to the students' own plans.)

Category II. How Scientists Function

IIa. Science as Research. The students used certain words repeatedly to indicate their responses to the term 'science'. Some of them referred to the activities of scientists. In this category the frequencies are as follows:

Term	Number of times used
Laboratories	21
Research	20
Experiments	17
New fields or discoveries	10
Test tubes	6
Careful work	1
Exact measurements	1

Some students elaborated on these ideas in rather fascinating ways, as these examples suggest:

> "I think of laboratories - excitement and the work attached."
> "Laboratory - very clean things; very analytical things."
> "Experiments - new ways of developing algae."

And there had to be at least one like this:

> "Just a lot of tubes and test tubes. Fancy stuff like the equipment you see in Buck Rogers."

IIb. Science as Technology. Many students relate science only to technology. Others have a composite picture which includes both pure and applied science. The references in the category of technology tallied as follows:

Term	Number of times mentioned
Technology or Technological Advances	16
Inventions	6
Discovery as invention (e.g. discovery of the electric light)	4
Miscellaneous (machinery; advances like automobiles)	2

Category III. The Uses of Science

Correctly or incorrectly, the students think of the outcome of science when they hear the term. Some of the responses of this nature are listed here.

Term	Frequency
Space (or related terms)	21
Medicine (or cures for disease)	7
Environment	5
Atomic energy; nuclear warfare	2
Making man (life, the world) better (easier)	11

Category IV. Scientists

One group of responses referred to the people engaged in science:

Term	Frequency
Scientist	11
Actual people (Einstein - 2, Newton - 1, Edison - 1)	4
"Men in white coats"	6
Miscellaneous (people studying - 1, Scholarly people who like books - 1, The Mad Scientist - 1)	3

Category V. Personal Reactions

A few students responded from emotion, some favorably, more not:

Favorable (Science is curiosity; Science is a challenge.)	2
Neutral (Science is very complicated)	1
Unfavorable (Don't like it; Very unpleasant; Not creative; Don't enjoy studying science; Not exciting)	5

Category VI. Science Is Universal

This category cannot be analyzed in the same fashion as the others since it contains a welter of disparate ideas. It also yields some of the most interesting and delightful responses. These are the students who see science as "an all-encompassing subject" (one of the responses). There are forty of these, and their flavor may be judged by the following sampling:

"Everything comes from science."

"Nature."

"The study of the things of the past, present, and future."

"Little insects and everything like that from the beginning. Actually it is the study of anything."

"Searching for knowledge. Trying to find out answers to questions."

"The study of material things and the laws and the ways of the universe."

A few of the statements collected simply defy categorization. One example is offered to represent this small class:

"Science as it is used today: something abstract, something hidden away from the everyday world; not really part of your life - like it doesn't exist."

Questions one, two, and three as a group sought to identify whether students had a clear and consistent definition of science, whether a distinction could be made between pure and applied research, and whether there was positive or negative feeling about science among the students. Overall, about 158 students could name some scientists; about 121 could make some distinction between science and technology. But whereas 126 students expressed support for pure science, 159 had supportive statements about technology as long as some external control and guidance were supplied to such efforts. There seemed to be strong support for the uses of science to "make life better," rather more so than for pure science "unrelated to the real problems." There seems no doubt that these students are caught up in a general societal pressure towards accountability and social orientation for scientific research. This verifies the findings from the opinionnaire.

Continuing Physics Education

In the fourth question the interest shifted to the possibility that the student might want to continue in physics beyond high school. We were also interested in the school personnel with whom he may have communicated and the content of their message. Over one hundred (115) students indicated continuing interest in physics. People influencing their positive decisions included: guidance counsellors (48), teachers (34), family (11). Guidance counsellors were specifically mentioned as making no input in only 16 cases. Several individuals commented upon the perceived, current plight of physicists in the job market. The following is typical, "I would have seriously con-

sidered going into physics except for the reported lack of a future in it...There have been a lot of stories about people who graduate from college and go on welfare." Another student had visited a local university and became alarmed when the professor claimed there was no demand for scientists. Since then he has changed his career orientation.

Physics Classrooms

Question five began to explore the nature of the physics experience in high school. It was specifically directed towards enjoyment. Of the 210 students, only 133 were willing to say that the physics class was enjoyable, 80 for class reasons, 65 for personal reasons. On the other hand, only 32 students would say they were not enjoying their high school experience in physics. Many others were quite noncommital.

In question six an attempt was made to have the student describe the normal scene in his physics class. Of particular interest were the roles assumed by teachers or by students, and the kind of controlling influence at work. In short, we explored what education researchers would call the social climate of the room. With regard to student role, there was a fairly even split. Eighty students felt they played an active role in class pacing, discussions, and general direction. One hundred and one felt a much more passive role was insisted upon. Said one such person, "Our teacher moves with the speed of light and all we do is act like mirrors reflecting back what he wants!" The part of the question relating to teacher style was equally split, 91 claiming their teachers were authoritarian while 95 assumed greater autonomy for students resulting from a more indirect form of teacher intervention.

Question seven identified the teacher as the sole determiner of pedagogical strategy (laboratory, lecture, homework, etc.) in 108 responses. A surprising 72 students felt that even this prerogative of the teacher was open to class discussion and modification, thus reflecting a fairly open system by typical physics class standards. Eighty-two students could cite options mutually taken by teacher and student, especially in the areas of laboratory projects or independent study.

The High School Laboratory

The laboratory experience became the center of attention in question eight. Generally lab exercises are illustrative of topics already covered in class (155). Rarely is there a chance to inquire into ideas and questions that haven't already been fully explained in class (91). Most teachers provide tightly scheduled work sheets which leave only a "filling in the blanks" exercise for students (118). Students feel that the laboratory work required of them amounts to little or no influence in what they learn or even in how they are graded by the teacher (132).

In a generally positive and optimistic set of interviews, this result of the question on laboratory experiences is the most dismal. Students find their laboratory hours "dull," "tedious," and "not useful in understanding." Some quotes from a variety of students:

"I can't see where the labs help us that much with the textbook."

"We wouldn't be trusted with the equipment."

"I can't understand because I don't know where the formulas come from."

"Labs are just demonstrations that the teacher sets up while he goes over the theory."

"Our lab reports are never corrected."

It would certainly seem that work remains to be done in a curricular and pedagogical sense upon the role of laboratory instruction, and the styles under which it might succeed.

The objectives which the student perceives the teacher setting for the class are based upon the kinds of experiences he provides for students. This perception is the content of question nine. In particular, a set of objectives, collected from the literature of physics teaching, were typed individually upon index cards. The students were asked to rank the cards (objectives) from highest to lowest in terms of: (1) What he felt the teacher believed, based on class experience; (2) What he, the student would like to see as a set of class objectives. The results have already been discussed and compared to the teachers' own statements of goals and objectives. To reiterate, it was found that both teachers and students placed a very low value upon cultural and historical aspects of physics and on the understanding of the role of science in our culture. Highest priority continues to be placed on mathematical and verbal "understanding" of the major concepts and principles of the discipline.

The Nature of Physics

The final question was epistemological in nature. Perhaps the 12th grade physics student is not yet capable of coming to grips with questions about physical reality, about validity and "truth" in scientific knowledge. In any case we wished to explore these dimensions of his understanding. As expected, most intelligible answers presented a static, dogmatic view of the world of science. There seems little understanding of notions of inquiry in an epistemological sense, even though some "problem solving method" could almost always be parroted. Certainly our exploration of the laboratory in high school physics would have predicted this, for if no phenomenological feel for the science is being conveyed, if no "explorations" are encouraged, it is difficult to see how this depth of insight could develop.

SUMMARY

Introduction

A study which is conducted for the purpose of gathering data has completed its mission when that data is recorded and reported. In the previous pages of this document, the observations of major importance made during the study have been described and tabulated. Obviously, choices have been made concerning topics to include and the emphasis each of these should receive. Many details have been omitted here; some of these will receive attention in more analytical reports to follow. At this time, it is appropriate to be as factual and objective as possible.

Yet a simple recital of findings is by itself a sterile presentation. Verbal descriptions meant to summarize a spectrum of results may convey information on cases in the tails of the distribution better than they highlight peaking around a central tendency. This summary is included to counteract such misleading impressions. We will attempt to call attention, with as little bias as possible, to those results which do stand out, amidst the variations and uncertainties, as valid and reliable pieces of information about the teaching of physics in the high schools.

Schools and Facilities

No matter what the size or location of the school, the general type and level of physics taught and the role physics plays in the curriculum is an invariant. A high school physics course almost always covers the major areas of classical physics in a quantitative way that includes laboratory measurement and data analysis, the development of theoretical models and theories, and applications and problem solving using algebra. This course is taught to twelfth grade students who have already studied biology and chemistry at the high school level. The percentage of twelfth graders enrolled in physics does vary significantly from school to school, with urban schools on the low end of the spectrum. Despite the variation, it is true that very few students who are not intending to enter college enroll in physics.

The amount of money spent on physics teaching materials per student varies over more than a factor of two for the schools in this study. Since apparatus is the most expensive single item, this variation may simply reflect differences in the motivation of teachers to stress laboratory work and the ease with which this can be done. There is some evidence to indicate that factors other than money place the primary limitations on innovations in general and on an emphasis on laboratory work in particular.

The use of course materials developed by the nationally-supported project groups is widespread, though considerably more prevalent in the suburban schools than in the urban schools. However, a striking observation is that the longer specific project course materials are available, the more likely one is to find <u>some</u> influence of that project on any particular course he studies, but the <u>less</u> likely he is to find any course which uses those project materials exclusively. Among the textbooks written privately, none stands out as the clear choice of a large fraction of the high school physics teachers.

Most schools seem to be moderately well stocked with commercial demonstration apparatus and relatively poorly equipped with built-in technical facilities and furniture conducive to performing demonstrations. Even less available are budgeted funds for supporting personnel such as typists, paper-graders, technicians, and teaching assistants.

The Teachers

The science backgrounds of the majority of the teachers in this study are much better than those of typical high school physics teachers reported by other investigators in recent years. Possibly a bias was introduced as a result of the fact that teachers could refuse to participate in the study without embarrassment. A significant majority of the teachers have enjoyed one or more opportunities to benefit from summer institute science courses. A smaller but significant number subscribe to and read one or more professional journals. A small minority attend professional meetings.

The majority of the teachers believe that prospective scientists should be taught a physics course which emphasizes experimental work in high school. Indeed, most do include laboratory work, but it does not always play a dominant role. An even larger majority of teachers believe other kinds of students should study a course which uses an historical-cultural approach, but few have either such students or such courses. Among a variety of stated courses objectives, one stood out as a clear first choice: "a verbal and mathematical understanding of the topics covered in physics."

A large majority of teachers feel that they conduct a "Rationally Prescribed" course, that is, a course in which behavior is justified by some understood, logical, enlightened system. About half (a plurality) feel that the main function of the laboratory is to demonstrate physical concepts and laws. The major limitations on better instruction are too little space and an excessively rigid schedule, say the teachers in this study.

The teachers are generally supportive of scientific research, but no more so than their students.

Physics Classrooms

Students spend more time engaged in laboratory work than in any other single classroom activity. Discussion and lecture sessions - often combined - are also used extensively. Relatively little time is devoted to learning through the use of audiovisual aids or other modern teaching devices. Independent study time is still relatively rare but not unknown.

Students generally see their teacher as in direct control of classroom proceedings, yet the majority believe that they themselves play an active role in what takes place. There are identifiable and marked differences concerning such perceptions among the different types of high school courses. The Project Physics course teachers have been unusually adept at conveying the impression that students direct their own learning, and in persuading students to read original writings. Teachers who use PSSC materials succeed in encouraging their students to seek in their own way

answers to theoretical and experimental problems, and in recognizing the importance of laboratory work. Both groups are on the average more successful than other teachers in generating a variety of activity and positive attitudes among their students toward physics.

Students did seem to feel that their tests are fair and appropriate. The majority assert that test questions require verbal as well as mathematical understanding, and agree that some test questions are based on things learned in the laboratory. There was little difference among the attitudes of students of the different kinds of courses toward examination content or testing procedures.

Students

Student attitudes toward the value of science to society are remarkably favorable. They also seem to feel that scientists do worthwhile and challenging work. However, the difficulty of doing science, and perhaps the appeal of other fields, appears to discourage about half from wanting to pursue science as a career.

There is little evidence that students have a very clear or detailed understanding of how scientists function. They do seem to associate science with laboratory experiments and research. There is some evidence that students confuse science and technology. In addition, students generally fail to perceive the creative aspects and evolving character of science; they view it as a dogmatic and static discipline.

The documentation for and details surrounding these highlights are contained in the tables and narrative paragraphs of the main body of this report. Before one can judge whether or not the picture painted here is bright or dark, one must wait to see whether later studies show that the derivative of the curve which passes through the point described in this study is positive or negative.

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APPENDICES

INSTRUMENTS FOR STUDY OF PHYSICS TEACHING

APPENDIX A: INVESTIGATOR'S CHECKLIST OF ACTIVITIES DURING ON-SITE VISITS

SCHOOL _____ TEACHER _____

_____ PRINCIPAL _____

_____ WEEK OF _____

PRINCIPAL'S INTERVIEW (Name) _____ (Day and Hour) _____

TEACHER'S INTERVIEW _____

COUNSELLOR'S INTERVIEW _____

OTHER? _____

CLASS RECORDING DATES AND TIMES 1. _____

2. _____

CLASS TESTING PERIOD _____

FACILITIES CHECKLIST COMPLETE? Yes No

PERSONAL PROFILE COMPLETE? Yes No

SCHOOL DATA SUMMARY COMPLETE? Yes No

STUDENT INTERVIEWS:

NAME _____ DATE & TIME _____

_____ _____

_____ _____

_____ _____

_____ _____

APPENDIX B: PERSONAL PROFILE QUESTIONNAIRE
(The following questionnaire was completed by the teacher of each course studied.)

Please answer as many items as you can. In some instances the question can be answered by checking the appropriate answer. Where a short sentence is necessary please write legibly.

1. Which grades are enrolled in your school? _____

2. Approximately when was your school building built? _____

3. When was the science facility last remodelled or renovated? _____

4. What is the approximate total enrollment of your school? _____

5. How many students take a course in physics each year? _____

6. How would you classify your school with respect to the area it served? (Check only one.)

____ Urban: Stable population
____ Urban: Transient population
____ Urban: Inner City
____ Suburban: Upper income level
____ Suburban: Middle income level
____ Small town
____ Rural
____ Other _____

7. How is your school best characterized? (Check only one.)

____ Comprehensive education
____ Technical education
____ College preparatory
____ Other _____

8. Please estimate the number of students in your school enrolled in the following courses for the years indicated:

	PSSC	Project Physics	Other
1968-69			
1969-70			
1970-71			
Next year			

9. If any of the following new science courses have been adopted in your school, which year was the adoption made?

PSSC _____
Project Physics _____
CBA _____
CHEMS _____
BSCS _____
IPS _____
ESCP _____
Other (specify) _____
_____
_____

10. List any new courses in other subject areas that have been adopted in the last five years if you know of them. (Use abbreviations if appropriate.)

_____

11. If you had free choice to teach any subject that you wished, which would be your first choice?

_____

12. Employment Record. List professional experience of the past 10 years in teaching and work related to teaching. Do not list odd jobs or summer employment outside of teaching.

Dates	Employer	Nature of Activity

. . . . . .

13. Check your certification status:
____ No certificate
____ Temporary or emergency
____ Permanent or fully accredited

Certification deficiency (if any) is in:
____ Science or mathematics
____ Education
____ Both
____ Other

14. Years of teaching experience by this June in:

a. Elementary school (grades 1-6): _____ years, from _____ to _____
b. Junior High school (grades 7-9): _____ years, from _____ to _____
c. High school (grades 9-12): _____ years, from _____ to _____
d. Other - specify: _____ years, from _____ to _____

15. List your complete teaching schedule for the current or most recent term; periods are ____ minutes long.

Course or other Assignment	Grade or Level	Periods per Week

. . . . . .

16. Science and mathematics teaching experience.

Subject	Grade Levels	Years Experience
Biology		
Chemistry		
Earth Sciences		
General Science		
Mathematics		
Physics		

17. College or university education.

Institution	School or Department	Years From	Years To	Degree	Major Subject	Minor Subject(s)

18. List all programs (four weeks or more in length) specifically for science or mathematics teachers that you have attended. Include all Summer Institutes (SI), In-Service Institutes (ISI) and Academic Year Institutes (AYI), and all Research Participation (RPHST) and Cooperative College-School Science (CCSS) programs, in which you have participated, whether NSF-supported or not and regardless of subject matter. Also list any Fellowships (FEL) you have received. Use a separate line for each summer and a separate line for each academic year. Use additional sheet if necessary.

Name of Host Institution	State (if not in name)	Year	Type of Program: SI, AYI, etc.	Length in weeks

19. Academic preparation: In this section show for every course studied in college or graduate school in the fields listed below: (a) the course number as recorded on your transcript, (b) the descriptive title of the course, (c) the year it was taken, (d) number of semester-hours credit received (multiply by 2/3 to convert quarter-hours to semester hours; record amount in column U if undergraduate, column G if graduate credit).

Course Number	Descriptive Course Title	Year Taken	Semester Hours U	Semester Hours G
	BIOLOGICAL SCIENCE			
	CHEMISTRY			
	PHYSICS			

Course Number	Descriptive Course Title	Year Taken	Semester Hours U	Semester Hours G
	MATHEMATICS			
	EARTH SCIENCE (Astronomy, Geology, etc.)			
	MATHEMATICS EDUCATION OR SCIENCE EDUCATION			

20. In comparison with the above record of courses, make an evaluation of the present state of your knowledge of the various subject fields:

    (a) The above record fairly represents my present background in the field(s) of _____

    (b) The record includes substantial material no longer familiar to me in the field(s) of _____

    (c) My present knowledge is more extensive than shown by the record in _____

21. What professional journals and scientific publications do you read regularly? _____

22. List the technical and professional science, chemistry, mathematics, physics, biological science, and education organizations (local, state, and national) of which you are a member:

    _____ _____

23. List the most recent professional or academic meetings or conferences you have attended specifically relevant to the teaching of science:

    _____

24. Are there other teachers with whom you can interact professionally regarding your physics teaching? ___Yes ___No

25. List any professional recognitions, awards, publications or other honors:

    _____

APPENDIX C: PHYSICS CURRICULUM RESOURCES CHECKLIST
(The following checklist was completed by the teacher of each course studied.)

Introduction

This checklist is a tabulation of all the curriculum resources for the Harvard Project Physics and Physical Science Study Committee courses and a representative traditional program.

The objectives of the checklist are:

1. To describe the texts and related materials used in a particular program.
2. To assess the availability and\or ownership of film loops, transparencies, films and programed materials.
3. To assess the resources of lab equipment for particular experiments and demonstrations.
4. To ascertain the role and extent each of the various resources plays in the process of teaching a physics course.
5. To find out the extent to which the various resources of the new physics curriculum (PSSC, HPP) have been incorporated into the traditional program.

Procedures

Please check the appropriate spaces on the checklist sheets indicating the condition that best describes your teaching situation. At the bottom of each column approximate the percent of checked spaces for that category.

Basic Course Materials

Make note of the basic course texts and materials and other supplementary basic course resources where appropriate.

Transparencies, Film loops, and Films

Check the spaces that describe the status of these resources and the pedagogical function they have in your program.

Experiments and Demonstrations

Check the spaces that describe the status of your laboratory with regard to the equipment that is required to perform the particular experiment or demonstration indicated and its pedagogical function in your program.

I. HPP Basic Course

1. Teachers guides:	complete set	yes____	no____
	partial set	yes____	no____
	which volumes	_____	
2. Student guides:	complete set for whole class	yes____	no____
	partial set	yes____	no____
	which volumes and how many	_____	

3. Student lab guides:
   - complete set for whole class — yes____ no____
   - partial set — yes____ no____
   - which volumes and how many — _____
4. Physics readers:
   - complete set for whole class — yes____ no____
   - partial set — yes____ no____
   - which volumes and how many — _____
5. Programed instruction booklets:
   - Vectors Part I — # _____
   - Vectors Part II — # _____
   - Vectors Part III — # _____
   - Kinetic Molecular Theory — # _____
   - Waves — # _____
6. Achievement tests:
   - complete sets — # _____
   - partial sets - which volumes & how many — _____

II. PSSC Basic Course

1. Teachers guides:
   - complete set — yes____ no____
   - partial set — yes____ no____
   - which volumes — _____
2. Student texts:
   - complete set for whole class — yes____ no____
   - partial set — yes____ no____
   - which volume and how many — _____
3. Laboratory guides:
   - complete set for whole class — yes____ no____
   - partial set — yes____ no____
   - which volume and how many — _____
4. PSSC tests:
   - complete set for whole class — yes____ no____
   - partial set — yes____ no____
   - which volume and how many — _____
5. Science Study Series: (total number = 56)
   - number of titles — _____
   - number of volumes — _____

III. Traditional Course

1. Text title & publishing date — _____
2. Teachers guide — yes____ no____
3. Student texts:
   - complete set for whole class — yes____ no____
4. Lab manual:
   - Title & publishing date — _____
   - complete set for whole class — yes____ no____
5. Other material

IV. Hybrid Course

Explain:

HPP TRANSPARENCIES LIST

			is used	is not used	not used but would like to	school owned	borrowed readily avail.	borrowed difficult inconvenient	unavailable
Unit 1	T0	Stroboscopic Photographs							
	T1	Stroboscopic Measurements							
	T2	Graphs of Various Motions							
	T3	Instantaneous Speed							
	T4	Instantaneous Rate of Change							
	T5								
	T6	Derivation of $d=v_1t + 1/2\ at^2$							
	T7								
	T8	Tractor-log Paradox							
	T9	Projectile Motion							
	T10	Path of a Projectile							
	T11	Centripetal Acceleration							
	T12								
Unit 2	T13	Stellar Motion							
	T14	Celestial Sphere							
	T15	Retrograde Motion							
	T16	Eccentrics and Equants							
	T17	Orbit Parameters							
	T18	Motion Under a Central Force							
Unit 3	T19	One-Dimensional Collisions							
	T20	Equal Mass Two-D Collisions							
	T21	Unequal Mass Two-D Collisions							
	T22	Inelastic Two-D Collisions							
	T23	Slow Collisions							
	T24	The Watt Engine							
	T25	Superposition							
	T26	Square Wave Analysis							
	T27	Standing Waves							
	T28	Two-slit Interference							
	T29	Interference Pattern Analysis							
Unit 4	T30	The Speed of Light							
	T31	E Field Inside Conducting Spheres							
	T32	Magnetic Fields and Moving Charges							
	T33	Forces Between Current Carriers							
	T34	The Electromagnetic Spectrum							
Unit 5	T35	Periodic Table							
	T36	Photoelectric Mechanism							
	T37	Photoelectric Equation							
	T38	Alpha Scattering							
	T39	Energy Levels - Bohr Theory							
Unit 6	T40	Separation of α, β, γ, Rays							
	T41	Rutherford's Particle "mousetrap"							
	T42	Radioactive Disintegration Series							
	T43	Radioactive Decay Curve							
	T44	Radioactive Displacement Rules							
	T45	Mass Spectrograph							
	T46	Chart of the Nuclides							
	T47	Nuclear Equations							
	T48	Binding Energy Curves							
		Percent of categories checked							

HPP FILM LOOP LIST

		is used	is not used	not used but would like to	school owned	borrowed readily avail.	borrowed difficult inconvenient	unavailable
Unit 1	L1 Acceleration Due to Gravity, Meth.I							
	L2 Acceleration Due to Gravity, Meth.II							
	L3 Vector Addition I-Velocity of a Boat							
	L4 A Matter of Relative Motion							
	L5 Galilean Relativity I							
	L6 Galilean Relativity II							
	L7 Galilean Relativity III							
	L8 Analysis of a Hurdle Race-I							
	L9 Analysis of a Hurdle Race-II							
Unit 2	L10 Retrograde Motion-Geocentric Model							
	L10aRetrograde Motion of Planets							
	L11 Retrograde Motion-Heliocentric Model							
	L12 Jupiter Satellite Orbit							
	L13 Program Orbit I							
	L14 Program Orbit II							
	L15 Central Forces-Iterated Blows							
	L16 Kepler's Laws							
	L17 Perturbations							
Unit 3	L18 One-Dimensional Collisions							
	L19 Further Examples of One-D Collisions							
	L20 Perfectly Inelastic One-D Collisions							
	L21 Two-Dimensional Collisions							
	L22 Further Examples of Two-D Collisions							
	L23 Perfectly Inelastic Two-D Collisions							
	L24 Scattering of a Cluster of Objects							
	L25 Explosion of a Cluster of Objects							
	L26 Finding the Speed of a Bullet I							
	L27 Finding the Speed of a Bullet II							
	L28 Recoil							
	L29 Colliding Freight Cars							
	L30 Dynamics of a Billiard Ball							
	L31 A Method of Measuring Energy-Nails...							
	L32 Gravitational Potential Energy							
	L33 Kinetic Energy							
	L34 Conservation of Energy I-Pole Vault							
	L35 " of Energy II-Aircraft Takeoff							
	L36 Kinetic Energy							
	L37 Reversibility of Time							
	L38 Superposition of Waves							
	L39 Standing Waves on a String							
	L40 Standing Waves in a Gas							
	L41							
	L42 Vibrations of a Rubber Hose							
	L43 Vibrations of a Wire							
	L44 Vibrations of a Drum							
	L45 Vibrations of a Metal Plate							
Unit 4	L41 Standing Electromagnetic Waves							
	L42, L43, L44, L45							
Unit 5	L46 Production of Sodium by Electrolysis							
	L47 Thomson Model of the Atom							
Unit 6	L48 Rutherford Scattering							
	L49 Collisions with Unknown Object							
	Percent of categories checked							

HPP FILM LIST

			is used	is not used	not used but would like to	school owned	borrowed readily avail.	borrowed difficult inconvenient	unavailable
Unit 1	F1	Straight-line Kinematics (PSSC)							
	F2	Inertia (PSSC)							
	F3	Free-fall & Proj. Motion (PSSC)							
	F4	Frames of Reference (PSSC)							
	F5	Vector Kinematics (PSSC)							
Unit 2	F6	Universe (NASA)							
	F7	Mystery of Stonehenge (McGraw)							
	F8	Frames of Reference (PSSC)							
	F9	Planets in Orbit (EBF)							
	F10	Elliptic Orbits (PSSC)							
	F11	Measuring Large Distances (PSSC)							
	F12	Of Stars and Men (Columbia Univ.)							
	F13	Tides of Fundy							
	F14	Harlow Shapley (EBF)							
	F15	Universal Gravitation (PSSC)							
	F16	Forces (PSSC)							
	F17	The Invisible Planet							
	F18	Close-up of Mars							
Unit 3	F17	Elements, Compounds & Mixt. (PSSC)							
	F18	The Perfection of Matter (Nuffield)							
	F19	Elastic Coll. & Stored Energy (PSSC)							
	F20	Energy and Work (PSSC)							
	F21	Conservation of Energy (PSSC)							
	F22	Mechanical Energy and Ther. En. (PSSC)							
	F23	Demonstrating the Gas Laws (CORONET)							
	F24	Gas Laws & Their Applic. (EBF)							
	F25	Molecular Theory of Matter (EBF)							
	F26	Progressive Waves, Transv. & Long.							
	F27	Stationary Longit. Waves (McGraw)							
	F28	Stationary Transverse Waves (McGraw)							
	F29	Sound Waves in Air (PSSC)							
Unit 4	F30	Speed of Light (PSSC)							
	F31	Introduction to Optics (PSSC)							
	F32	Coulomb's Law (PSSC)							
	F33	Electrons in Uniform Mag. Field (MLA)							
	F34	Electromagnetic Waves (PSSC)							
Unit 5	F35	Definite & Mul. Proportions (PSSC)							
	F36	Elements, Compounds, & Mixtures (MLA)							
	F37	Counting Electrical Charges (MLA)							
	F38	Millikan Experiment (PSSC)							
	F39	Photoelectric Effect (MLA)							
	F40	The Structure of Atoms (MH)							
	F41	Rutherford Atom (MLA)							
	F42	A New Reality (IFB)							
	F43	Franck-Hertz Experiment (MLA)							
	F44	Interference of Photons (MLA)							
	F45	Matter Waves (MLA)							
	F46	Light: Wave & Quant. Theories (CORONET)							
Unit 6	F47	Discovery of Radioactivity (IFB)							
	F48	U238 Radioactivity Series (MH)							
	F49	Random Events (PSSC)							
	F50	Long Time Intervals (MLA)							
	F51	Isotopes							
	F52	The Linear Accelerator (MH)							
	F53	Positron-electron Annihilation (EBF)							
	F54	Fission (MH)							
		Percent of Categories Checked							

PSSC FILM LIST
(Listed by text chapter)

	Chapter	is used	is not used	not used but would like to	school owned	borrowed readily avail.	borrowed difficult inconvenient	unavailable
Part 1	1							
	2 Short Time Intervals							
	Time and Clocks							
	Long Time Intervals							
	3 Measuring Large Distances							
	Measuring Small Distances							
	4 Change of Scale							
	5 Straight Line Kinematics							
	6 Vectors							
	Vector Kinematics							
	7							
	8 Elements, Compounds, & Mixtures							
	Definite & Multiple Proportions							
	Crystals							
	9 Behavior of Gases							
	Random Events							
	10 Measurements							
Part 2	11 Introduction to Optics							
	12							
	13							
	14 The Pressure of Light							
	The Speed of Light							
	15 Simple Waves							
	16							
	17 Sound Waves in Air							
	18							
Part 3	19 Forces							
	Inertia							
	Inertial Mass							
	20 Falling Bodies							
	Deflecting Forces							
	Periodic Motion							
	Frames of Reference							
	21 Universal Gravitation							
	Elliptic Orbits							
	22							
	23 Elastic Collisions & Stored Energy							
	Momentum, Energy & Center of Mass							
	Energy and Work							
	24							
	25 Mechanical & Thermal Energy							
	Conservation of Energy							
Part 4	26							
	27 Coulomb's Law							
	Millikan Experiment							
	Coulomb's Force Constant							
	Electric Fields							
	Electric Lines of Force							

PSSC FILM LIST (Cont.)

	is used	is not used	not used but would like to	school owned	borrowed readily avail.	borrowed difficult inconvenient	unavailable
Part 4 28 Counting Electrical Charges in Motion							
Elementary Charges & Transfer of Kinetic Energy							
EMF							
Electrical Potential Energy & Potential Difference - Parts I & II							
29							
30 A Magnet Laboratory							
Electrons in a Uniform Magnetic Field							
Mass of the Electron							
31 Electromagnetic Waves							
32 Rutherford Atom							
33 Photons							
Interference of Photons							
Photo-electric Effect							
Matter Waves							
34 Franck-Hertz Experiment							
Advanced Topics							
1 Angular Momentum-A Vector Quantity							
2							
3							
4 Time Dilation							
5 Ultimate Speed							
Electron-Positron Annihilation							
6							
7 Barrier Penetration-Ripple Tank Wave Phenomena III							
Percentage of categories checked							

PSSC EXPERIMENT LIST

			class experiment	group experiment	individual experiment	demonstration	not used	whole class	part class	demonstration	none
Part 1	1	Short Time Intervals									
	2	Large Distances									
	3	Analysis of an Experiment									
	4	Motion: Velocity & Acceleration									
	5	Molecular Layers									
	6	Natural Temperature Scale									
Part 2	1	Reflection from a Plane Mirror									
	2	Images Formed by a Concave Mirror									
	3	Refraction									
	4	Images Formed by a Converging Lens									
	5	The "Refraction" of Particles									
	6	Waves on a Coil Spring									
	7	Pulses in a Ripple Tank									
	8	Periodic Waves									
	9	Refraction of Waves									
	10	Waves and Obstacles									
	11	Waves from Two Point Sources									
	12	Interference and Phase									
	13	Young's Experiment									
	14	Diffraction of Light by Single Slit									
	15	Resolution									
	16	Measurement Short Distances by Interfer.									
Part 3	1	Changes in Velocity with Constant Force									
	2	Dependence of Acceleration on Force & Mass									
	3	Inertia and Gravitational Mass									
	4	Forces on a Ball in Flight									
	5	Centripetal Force									
	6	Law of Equal Areas									
	7	Momentum Changes in an Explosion									
	8	The Cart and the Brick									
	9	A Collision in Two Dimensions									
	10	Simulated Nuclear Collisions									
	11	Changes in Potential Energy									
	12	The Energy of a Simple Pendulum									
	13	A Head-on Collision									
Part 4	1	Electrified Objects									
	2	Electrostatic Induction									
	3	The Force Between Two Charged Spheres									
	4	The Addition of Electric Forces									
	5	Driving Force and Terminal Velocity									
	6	The Millikan Experiment									
	7	Charge Carried by Ions in Solution									
	8	Charge on a Capacitor									
	9	Energy Transferred by Electric Motor									
	10	The Magnetic Field of a Current									
	11	The Measurement of a Magnetic Field in Fundamental Units									
	12	The Mass of the Electron									
	13	Magnetic Field Near Long, Straight Wire									
	14	Randomness in Radioactive Decay									
	15	Spectrum of Hydrogen & Planck's Const.									
		Percentage of categories checked									

TRADITIONAL LABS

			class experiment	group experiment	individual experiment	demonstration	not used	whole class	part class	demonstration	none
Forces & Motion	1	Measuring Length									
	2	Measuring Volume									
	3	Determining Density									
	4	Pulleys									
	5	Levers									
	6	Principle of Moments									
	7	Center of Gravity									
	8	Equilibrant Forces									
	9	Inclined Planes									
	10	Friction									
	11	Components of a Force									
	12	Archimedes' Principle									
	13	Specific Gravity									
	14	Boyles' Law									
	15	Surface Tension & Capillary Action									
	16	Rotational Equilibrium									
	17	Speed									
	18	Acceleration									
	19	Inertia									
	20	Impulse & Momentum									
	21	Inertial & Gravitational Mass									
	22	Centripetal Force									
	23	SHM									
	24	Kinetic Energy									
Heat	25	Measurement of Temperature									
	26	Expansion of Solids & Gases									
	27	Specific Heat Capacity									
	28	Heat Exchange									
	29	Change of State, Fusion, Vaporization									
	30	Mechanical Equivalent of Heat									
Sound	31	Wavelength & Velocity of Sound									
	32	Pulses & Waves in a Spring									
	33	Standing Waves in a Wire									
Light	34	Reflection & Refraction of Water Waves									
	35	Interference from 2 Point Sources									
	36	Diffraction									
	37	Photometry									
	38	Reflection of Light									
	39	Refraction of Light									
	40	Image Formation by Lenses									
	41	The Lens Equation									
	42	Interference & Diffraction of Light									
	43	Color									
	44	Polarization of Light									
	45	Spectroscope									

TRADITIONAL LABS (Cont.)

		class experiment	group experiment	individual experiment	demonstration	not used	whole class	part class	demonstration	none
Electricity	46 Static Electric Charges									
	47 Wiring Electric Circuits									
	48 Electroplating									
	49 Voltaic Cells									
	50 Lead Storage Cells									
	51 Magnets & Magnetic Fields									
	52 Magnetic Field Around a Current									
	53 Electromagnets									
	54 Electric Motors & Generators									
	55 Electrical Resistance									
	56 Electrical Power, Energy & Costs									
	57 Series & Parallel Circuits									
	58 Induced EMF									
	59 Electromagnetic Induction									
	60 Impedance									
	61 Some Functions of a Vacuum Tube									
Atomic	62 Nuclear Radiation									
	Percentage of Categories Checked									

HPP EXPERIMENT LIST

		class experiment	group experiment	individual experiment	demonstration	not used	whole class	part class	demonstration	none
Unit 1	E1 Naked Eye Astronomy									
	E2 Regularity and Time									
	E3 Variations in Data									
	E4 Uniform Motion									
	E5 A 17th Century Experiment									
	E6 A 20th Century Version of Galileo's Experiment									
	E7 Measuring the Acceleration of Gravity - five methods									
	E8 Newton's Second Law									
	E9 Inertial & Gravitational Mass									
	E10 Trajectories-1 & 2									
	E11 Circular Motion 1									
	E12 Circular Motion 2									
Unit 2	E13 The Size of the Earth									
	E14 The Height of Piton (on the Moon)									
	E15 The Shape of the Earth's Orbit									
	E16 Using Lenses, Make & Use Telescope									
	E17 The Orbit of Mars									
	E18 The Inclination of Mar's Orbit									
	E19 Mercury's Orbit									
	E20 Step-wise Approximation to an Orbit									
	E21 Model of a Comet Orbit									
Unit 3	E22 Collision in One Dimension									
	E23 Collisions in Two Dimensions									
	E24 Conservation of Mechanical Energy									
	E25 Speed of a Bullet									
	E26 Hotness, Thermometers, & Temperature									
	E27 Calorimetry									
	E28 Monte Carlo Expt. on Molec. Collisions									
	E29 Behavior of Gases									
	E30 Introduction to Waves									
	E31 Sound									
Unit 4	E32 Young's Exp-Wavelength of Light									
	E33 Electric Forces I									
	E34 Electric Forces II-Coulomb's Law									
	E35 Currents and Forces									
	E36 Currents, Magnets, and Forces									
	E37 Electron Beam Tube									
	E38 Microwaves									
Unit 5	E39 Charge-to-Mass Ratio for Electron									
	E40 Measurement of Elementary Charge									
	E41 Electrolysis									
	E42 Photoelectric Effect									
	E43 Spectroscopy									
Unit 6	E44 Random Events									
	E45 Range of Alpha & Beta Particles									
	E46 Half-Life I									
	E47 Half-Life II									
	E48 Radioactive Tracers									
	Percentage of Categories Checked									

HPP DEMONSTRATION LIST

			performed	not performed	available	not available
Unit 1	D1	Recognizing Simple Motions				
	D2	Uniform Motion, Using Accelerometer and Dynamics Cart				
	D3	Instantaneous Speed, Using Strobe Photos				
	D4	Uniform Acceleration, Using Liquid Accelerometer				
	D5	Comparative Fall Rates of Light and Heavy Objects				
	D6	Coin and Feather				
	D7	Two Ways to Demonstrate the Addition of Vectors				
	D8	Direction of Acceleration & Velocity				
	D9	Direction of Acceleration & Velocity - an Air Track Demonstration				
	D10	Non-commutativity of Rotations				
	D11	Newton's First Law				
	D12	Newton's Law Experiment (Air Track)				
	D13	Effect of Friction on Acceleration				
	D14	Demonstrations with Rockets				
	D15	Making an Inertial Balance				
	D16	Action-reaction Forces in Pulling Rope-1				
	D17	Action-reaction Forces in Pulling Rope-2				
	D18	Reaction Force of a Wall				
	D19	Newton's Third Law				
	D20	Action-reaction Forces Between Car & Road				
	D21	Action-reaction Forces in Hammering Nail				
	D22	Action-reaction Forces in Jumping Upwards				
	D23	Frames of Reference				
	D24	Inertial vs Non-inertial Reference Frames				
	D25	Uniform Circular Motion				
	D26	Simple Harmonic Motion				
	D27	Simple Harmonic Motion (Air Track)				
it 2	D28	Phases of the Moon				
	D29	Alternate Demonstration for Model of Geocentric Motions				
	D30	Alternate Demonstration for Model of Heliocentric Motiors				
	D31	Plane Motion				
	D32	Conic Sections from Model				

HPP DEMONSTRATION LIST (Cont.)	performed	not performed	available	not available
Unit 3 D33 An Inelastic Collision				
D34 Range of a Slingshot				
D35 Diffusion of Gases				
D36 Brownian Motion				
D37 Wave Propagation				
D38 Energy Transport				
D39 Superposition				
D40 Reflection				
D41 Wave Trains				
D42 Refraction				
D43 Interference Patterns				
D44 Diffraction				
D45 Standing Waves				
D46 Tunable Oscillator				
Unit 4 D47 Electrostatic Demonstrations				
D48 The Electrophorus				
D49 Currents and Forces				
D50 Currents, Magnets and Forces				
D51 Electric Fields				
D52 Microwaves				
Unit 5 D53 Electrolysis of Water				
D54 Charge-to-Mass Ratio for Cathode Rays				
D55 Photoelectric Effect				
D56 Blackbody Radiation				
D57 Absorption				
D58 Ionization Potential				
Unit 6 D59 Mineral Audioradiograph				
D60 Naturally Occurring Radioactivity				
D61 Mass Spectrograph				
D62 Aston Analogue				
Percentage of Categories Checked				

APPENDIX D: PHYSICS TEACHING FACILITIES CHECKLIST
(The following checklist was completed by the teacher of each course studied.)

I Classrooom

Number of students in this class _____

1. Classroom is separate from the lab — Yes ____ No ____
2. Classroom and lab are combined — Yes ____ No ____
3. Classroom is used for physics only — Yes ____ No ____

Other uses of the classroom (include % of time) _____

Facilities in the classroom:

4. Demonstration table: None ____ Fixed ____ Movable ____
5. Demonstration table utilities: Gas ____ Water ____ Air ____ Variable electric source ____
6. Classroom seating: Desks ____ Tables ____ Fixed ____ Flexible ____ Number of seats ____
7. Chalkboard: Adequate ____ Inadequate ____ Fixed ____ Movable ____
8. Bulletin boards: Adequate ____ Inadequate ____ None ____
9. Display areas: Adequate ____ Inadequate ____ Shelves ____ Cases ____ Counter tops ____
10. Storage space: Adequate ____ Inadequate ____
11. Audio-visual:
    - Projection screen — Yes ____ No ____
    - Means for darkening room — Yes ____ No ____
    - Convenient electrical outlet for projection — Yes ____ No ____
    - T.V. cable — Yes ____ No ____
12. Partitions for dividing room: Yes ____ No ____

II Laboratory

1. Preparation room is separate from lab area: Yes ____ No ____
2. Preparation space exists in the lab area: Yes ____ No ____
3. Lab furniture is: Fixed ____ Flexible ____
4. Lab furniture consists of: Tables & chairs ____ No. ____; Long counter cabinets ____; Small group counter situations ____; Work area per pupil ____; Number of seats ____
5. Utilities in the lab: Gas ____ Air ____ Vacuum ____ Water ____ Variable electrical source ____
6. Utilities are located at: Each work space ____ Other ____
7. Chalkboard: Adequate ____ Inadequate ____ None ____
8. Bulletin boards: Adequate ____ Inadequate ____ None ____
9. Display areas: Adequate ____ Inadequate ____ Shelves ____ Cases ____ Counter tops ____
10. Areas for special projects: Yes ____ No ____ Adequate ____ Inadequate ____
11. Storage space: Adequate ____ Inadequate ____ Approx. Amt. ____
12. Dark room: Yes ____ No ____ Adequate ____ Inadequate ____

Major Laboratory Equipment:

13. Complete set of tools in lab: Yes ____ No ____
14. Refrigeration: Yes ____ No ____
15. Oven: Yes ____ No ____
16. Power supply units: Yes ____ No ____ #___
17. Air track: Yes ____ No ____ #___
18. Laser: Yes ____ No ____
19. Optical bench: Yes ____ No ____
20. Cathode-ray oscilloscope: Yes ____ No ____ #___
21. Microwave experimenter: Yes ____ No ____
22. Spectrometer: Yes ____ No ____
23. Rotational dynamics apparatus: Yes ____ No ____
24. Electronics kit: Yes ____ No ____
25. Polaroid camera: Yes ____ No ____ #___
26. Analytical balances: Yes ____ No ____
27. Telescope: Yes ____ No ____
28. Computer: Yes ____ No ____ Access___
29. Has equipment been borrowed or donated from the community? Yes ____ No ____
    What_____ From whom_____

III Instructional Support:

1. Lesson preparation area: None ____ OR
   a) desk in classroom Private___ Shared___
   b) desk in office with other physics teachers Private___ Shared___
   c) desk in office with other teachers Private___ Shared___
   Science___ Non-science___
2. Book shelves at desk: Adequate___ Inadequate___None___
3. Filing cabinets: Adequate___ Inadequate___None___
4. Professional library: Adequate___ Inadequate___None___
   # of volumes___ # of periodic.___
5. Typewriter: Private___ Shared___
   Central office___ None___
6. Duplicating procedures: Teacher must do ____
   Assistant teacher does ____
   Central office does ____
7. Audiovisual equipment:
   a) Teacher must obtain & return Yes ____ No ____
   Convenient___ Inconvenient___
   b) Teacher must set up projector Yes ____ No ____
   c) A.V. assistants are used Yes ____ No ____
8. Teacher has access to a complete machine shop: Yes ____ No ____
9. Space is provided for student notebooks and materials: Yes ____ No ____
   i.e. filing cabinets ___ lab cabinets ___ shelves ___
10. The school library has a physics section: Yes ____ No ____
    # of volumes___ # of periodic.___
11. A small physics library & study area exists: Yes ____ No ____
    In the classroom___ In lab___
    # of volumes___ # of periodic.___
12. A.V. carrels are provided for students: Yes ____ No ____
    Location: Physics classroom ____
    Physics laboratory____
    School library ____
    Other ____

APPENDIX E: BUDGETS
(The following form was completed by the teacher of each course studied.)

No. of physics students: ____

1) Funds for lab expendables:
   Total '71-'72 _____
   Amt. per physics pupil _____

2) Funds for lab capital expenditures:
   Total '71-'72 _____
   Amt. per physics pupil _____

3) Funds for curriculum resource materials:
   Total '71-'72 _____
   Amt. per physics pupil _____

4) Funds for A.V.
   Rentals _____
   Purchases _____

5) Funds for laboratory or teaching assistance:
   Total _____
   No. of hours per week _____

6) How does the teacher evaluate the allotment of funds in each of the foregoing categories with regard to the program he is trying to offer?

A-Adequate
I-Inadequate
CI-Critically Inadequate

1) Lab expendables _____
2) Lab capital expendables _____
3) Curriculum resource materials _____
4) A.V. _____
5) Lab or teaching assistance _____

7) How is purchasing handled?

a) Central business office — Yes ____ No ____
   Requisitions pooled for contract by bid — Yes ____ No ____
   Requisitions handled individually — Yes ____ No ____
   Other _____

b) School principal — Yes ____ No ____
c) Science supervisor — Yes ____ No ____
d) Head of science department — Yes ____ No ____
e) Physics teacher — Yes ____ No ____

8) Are funds available during the year? Yes ____ No ____

9) When was the most recent physics textbook (in quantity) purchase made? _____

10) When were the most recent major laboratory acquisitions made? _____

11) When was the most recent major curriculum resources acquisitions made? _____

APPENDIX F: PHYSICS TEACHING STUDY
(The following form was completed by the teacher of each course studied.)

Report for week ending Friday _____
Date

Daily Activities (Write in approximate percentage of time during each physics class for each kind of activity.)

	Lecture	Discussion	Problems by Teacher	Demonstration by Teacher	Laboratory	Demonstration by Student	Problems by Students	Films and Other A.V.	Quizzes	Tests	Other (Specify)
Monday											
Tuesday											
Wednesday											
Thursday											
Friday											

Weekly Summary (Write in requested information. Additional information reverse side.)

Specific objectives for week

_____

Topics covered (Text references would help)

_____

Assignments

_____

Laboratory experiences

_____

Films or other A.V. material

_____

APPENDIX G: PHYSICS TEACHING OPINIONNAIRE
(The following opinionnaire was completed by the students of each course studied.)

School _____ Date _____

The questions in this paper are an attempt to discover how you feel about this physics course you are enrolled in. It isn't a test, we don't even ask you for your name. We would like to have your honest opinion about what you think happens in your physics class.

Please answer every question. Read each statement carefully and think about how well it describes your own physics class. If the statement describes an event that constantly happens in this class mark an X over space 1, ALWAYS.
If it happens OFTEN, mark space 2.
If it happens SOMETIMES, mark 3.
If NEVER, mark 4.

There are 30 statements, you will have 15 minutes to complete.

1. Our teacher usually assists us in the lab by answering our questions with other questions rather than direct answers 1 2 3 4
2. I have an assigned partner or group I must work with in laboratory periods 1 2 3 4
3. The teacher encourages us to find out things for ourselves instead of asking someone else 1 2 3 4
4. Questions requiring us to state memorized formulas, laws, and theories are the most important ones on our tests 1 2 3 4
5. Our class discusses the problems faced by scientists in the discovery of a scientific principle 1 2 3 4
6. Our class experiences what physicists do and how they do it rather than reading about the resulting principles of physics . . . 1 2 3 4
7. Before we do a laboratory experiment we have an idea of what the results will be 1 2 3 4
8. The grades that I receive on my physics tests adequately reflect my understanding of physics as a science 1 2 3 4
9. There are punishments for certain types of rulebreaking of which all the class is aware 1 2 3 4
10. The objectives for the course are well explained and known to the class 1 2 3 4
11. Our classroom is a noisy and active place with no direction or purpose evident 1 2 3 4
12. Our tests include questions based on things we have learned in the laboratory 1 2 3 4
13. We have free lab periods when we can do whatever interests us, e.g., repeat previous experiments, design a new experiment, or perform some other experiment 1 2 3 4
14. The teacher joins the class more as a participant than as a leader during physics periods 1 2 3 4
15. Students determine the method or procedure for a laboratory experiment 1 2 3 4
16. Our laboratory work results in unresolved debates about concepts, methods or interpretations 1 2 3 4
17. Questions requiring us to draw conclusions from new data are asked on the tests 1 2 3 4

18. Films shown in class are well integrated with class topics through discussion and questions 1 2 3 4
19. Our classroom normally is a quiet and orderly place where everybody knows what will happen next 1 2 3 4
20. Students read the <u>original</u> writings of current or historical scientists as class work 1 2 3 4
21. Physics tests really measure mathematical ability rather than understanding of physics 1 2 3 4
22. Experiencing the difficulty of acquiring data in the laboratory is an interesting and valuable aspect of learning about physics in this class 1 2 3 4
23. Lab experiments prove what we have already learned 1 2 3 4
24. Our class discusses the validity of the evidence that is behind a scientist's conclusion 1 2 3 4
25. Much of a class period is spent listening to the teacher lecturing or demonstrating 1 2 3 4
26. The teacher is careful to hold back criticism at times when feelings of students would be unnecessarily hurt 1 2 3 4
27. Lab experiments are a regular weekly activity in this course 1 2 3 4
28. My teacher asks questions that cause us to think about the evidence that is behind statements that are made in the textbook 1 2 3 4
29. Questions requiring verbal understanding as well as mathematical understanding are asked on the tests 1 2 3 4
30. Our class is rather informal with not very many regulations and rules 1 2 3 4

APPENDIX H: SCIENCE OPINIONNAIRE
(The following opinionnaire was completed by the students of each course studied.)

School _____ Date _____

The questions in this paper are an attempt to discover how you feel about science. It isn't a test, we don't even ask for your name. We would like to have your honest opinion about what you think of the workings of science in our society.

Please answer every question. Read each statement carefully and think about how you feel about the item. If you STRONGLY AGREE, mark space 1 with an X.
If you just AGREE, mark space 2.
If you DISAGREE, mark space 3.
And if you STRONGLY DISAGREE, mark 4.

There are 30 statements, you will have 15 minutes to complete.

1. No one can foresee or predict what may come from the laboratories in the future 1 2 3 4

2. Few professions offer opportunties superior to those a scientist might encounter 1 2 3 4

3. Regardless how the results of science are used, the scientist himself must share a major part of the responsibility 1 2 3 4

4. The world would have been better off without some of the recent products of science 1 2 3 4

5. Scientific work is usually pretty far removed from everyday reality 1 2 3 4

6. Our high standard of living is an outgrowth of scientific advances. 1 2 3 4

7. Some kinds of experimental work should be prohibited 1 2 3 4

8. The fascination of research is the chance of a great discovery . . 1 2 3 4

9. Science depends upon free and open communication 1 2 3 4

10. The good science has done mankind outweighs the problems it has created 1 2 3 4

11. Research in some fields should be given much more support 1 2 3 4

12. Only a small percentage of the population could qualify to become scientists 1 2 3 4

13. Modern science is incapable of solving today's problems 1 2 3 4

14. Minute increments, not great strides, will characterize future scientific growth 1 2 3 4

15. Secrecy is an important positive influence upon American science today 1 2 3 4

16. It might be well to retard scientific activity for a time 1 2 3 4

17. A scientific career offers a chance to do something really worthwhile 1 2 3 4

18. A good scientist considers the consequences of his professional activity 1 2 3 4

19. In recent years scientific research has been dominated by the government and the military 1 2 3 4

20. All that is left for scientists to do is to "fill in the gaps" of knowledge 1 2 3 4

21. Industrial profits, not science, is responsible for the pollution problem 1 2 3 4

22. Modern scientific workers are no different from other employees of large businesses 1 2 3 4

23. If all scientific work stopped, the world would not suffer 1 2 3 4

24. The rewards of a scientific career would not repay the effort involved 1 2 3 4

25. A scientist ought to be free to do whatever experimental work he feels is important 1 2 3 4

26. I would like to see all scientific research abandoned 1 2 3 4

27. Science does not cause problems, the misuse of science does . . . 1 2 3 4

28. The frontiers of science are exhausted 1 2 3 4

29. Much of scientific work is dull and routine 1 2 3 4

30. I would like to become a scientist 1 2 3 4

APPENDIX I: STUDENT SCHEDULE
(The following questions guided the interviewer during interviews of students.)

1. When the word "science" is used, what kinds of thoughts come to mind? What do you think about when you hear or use the word "science"?

   -Knowledge-oriented or product-oriented
   -Science or technology
   -Positive or negative images

2. Can you name any people you would consider to be scientists, either current or historical? (Explore implications of one or more of these for a definition of science. Is such a definition consistent with 1.?)

   -Distinguish science & technology or pure and applied science

3. Should this country continue to support scientific endeavors in the way it has done? Should support increase, decrease, or remain the same?

   -Pure science vs. technology
   -Priorities

4. Is there any possibility that you might want to continue in a physics course, or a physics related course, or even a career oriented towards physics later on? Has anybody in this school ever talked to you about physics or science in general as a career or as a college major? What kinds of things did he say?

   -Who in the school or outside?
   -What information?
   -How perceived?
   -How is the student made to feel about physics?

5. Are you enjoying your classes in the physics course this year? Why (or why not?)

   -Particular responses and general ideas
   -My class, my work, my teacher vs science, society, priorities

6. Could you try to describe the normal scene in your physics class? What role does your teacher play? What do you do, as a student in that situation, typically?

   -Authoritarian vs open
   -Teacher - leader, guide or participant
   - helpful or rejecting
   -Student initiation
   -Distinguish between lectures, labs, etc.

7. What kinds of different techniques and situations can be used by the teacher or by individual students to help you learn physics? For example, a laboratory class can be considered an available situation or technique. What others are typically available?

   -Lecture
   -Film and AV
   -Discussion

-Questions to and from students
-Tests, assignments, problems
-Demonstrations
-Individual projects
-Open door laboratories

8. Let's explore one of those techniques from the last question a little further. How often do you go into the laboratory? What are your experiences there like?

-Before or after coverage of topic in class
-Open vs closed exercises
-Labs for experiment, recipes, or demonstrations
-Lab reports, grades

9. If you were to judge from the normal physics class activities, what do you think your teacher's main objectives are? That is, what does he want you to be able to do, to know, to feel about physics? Remember your answer is to be based on only the normal classroom routine.

-Extend answer above

Follow with Objectives Card Sort
(1) As inferred to actually be from routine
(2) As student would prefer to see it

10. What do you think about physics knowledge? That is, what do you think of the ideas with which physicists describe the world: electrons, molecules, nuclei, etc.? How real are these things?

-Meaning of "real," "va[illegible]," "true"
-Constructed vs dogmatic knowledge

APPENDIX J: TEACHER SCHEDULE
(The following questions guided the interviewer during interviews with teachers.)

1. Do you think the views of students in general towards studying physics in your high school are undergoing changes? How about their attitudes towards further physics study or physics oriented careers? Would your answer be the same in both cases?

   -Image of science, positive or negative?
   -Economic factors
   -Intellectual excitement
   -Difficulty
   -Alienation from science generally

2. What approach to physics education in high school seems most appropriate to you? That is, which students should take physics and what should be the overall nature of the course(s)?

   -Physics for general or specific groups
   -Mathematics skills
   -College entrance or general education
   -Experiment oriented (PSSC) vs cultural-historical (HPP)

3. In your particular course in physics, do you have a specific set of objectives which you strive to reach? That is, why do you teach physics?

   -Nature of science
   -Vocational approaches
   -Knowledge of facts and laws
   -Attitudes, appreciation

   (Follow up with Objectives Card Sort.)

4. How would you describe yourself as a teacher? That is, what is your role as teacher in the classroom, what is the student's role? How would you organize the class with respect to leadership, control, discipline.

   -Open or closed
   -Participant teacher or leader
   -Students to "learn" or "be taught"
   -Authoritarian vs laissez faire

   (Note: Try to concentrate on Social System rather than teaching styles.)

5. What particular role do you see the laboratory playing in physics teaching?

   -When do students go into labs (before or after coverage of topic in class)?
   -Inquiry (initiating) vs. illustrative (reinforcing)
   -Lab report style, form requirement
   -Final evaluation in course, role of lab work in evaluation

6. What factors in your school situation present difficulties to you as a physics teacher? That is, are there any constraints imposed by student level, by administration, by budgets or space which prevent or hinder you from doing some things you would like to do as a physics teacher but can't, or which force you to modify your approach from some more ideal way?

   -Philosophy of teaching
   -Labs, open ended enquiry, money and supplies, school and community attitude
   -Regents exams, merit exam

7. How do you view scientific knowledge, in particular, in the discipline of physics? How real are the current conceptions of the physical world? What do you expect will change in the future?

   -Science as Enquiry vs Dogma
   -Meaning of "true," "valid," "real"
   -Role of assumptions
   -Kuhn, Margenau, Schwab
   -Role of models

8. What do you think the role of physics in our culture has been in the past? Are there any <u>real</u> changes occurring in that role today?

   -Real versus perceived changes
   -Industry, military, classified research
   -"Good" vs "bad" science
   -Science and technology
   -Morality, responsibility
   -Science-society interaction

9. What do you think about the money being spent on scientific research today? Would you continue it if you could choose? Which projects might you continue to support and which would you definitely abandon?

   -Lunar exploration
   -Nuclear energy uses
   -Supersonic aircraft
   -Heart and organ transplants
   -Genetics research
   -Pollution research
   -Ecology - environment projects

APPENDIX K: PRINCIPAL SCHEDULE
(The following questions guided the interviewer during interviews with principals.)

1. What approach to physics education in high school seems most appropriate to you? That is, in your opinion, what should be the overall nature of the physics course and which students should be encouraged to take physics?

   Guidelines:

   a. Should physics be taught in such a way as to appeal to all students or just to specific groups?

   b. Should high school physics be offered primarily for the college bound students, especially those who might major in the sciences, or should physics be considered an essential element in the general education of any high school student?

   c. Which physics course would best serve the needs of the students in your school, one that stressed laboratory experimentation, one that stressed applications of higher mathematics to physical problems, or one that stressed the cultural and historical values associated with physics and physicists?

2. How do curriculum innovations take place in your school?

   Guidelines:

   a. Who initiates curriculum innovations?

   b. What are the roles and responsibilities of teachers, department heads, curriculum coordinators, administrators, counsellors, school board members, etc., in curriculum innovation?

   c. Is there a well defined procedure to be followed? Who is involved?

   d. Who has a veto over suggested curriculum innovations? Under what conditions can a veto be exercised?

   e. Who is the most important person in determining if a suggested curriculum innovation will be adopted?

3. How are the budget decisions made for the physics program?

   Guidelines:

   a. What is the amount per pupil spent in physics versus other subjects?

   b. How is an extraordinary outlay of funds such as might be required for the adoption of a new physics program found?

4. Do any factors present difficulties or constraints upon the type of physics program you are offering or would like to offer?

   Guidelines:

   a. Is there sufficient space and equipment?

   b. Are college prep requirements or Regents or Merit Exams constraining?

   c. Does school board policy, community attitude, or the district philosophy of teaching effect the type of physics program offered?

APPENDIX L: COUNSELLOR SCHEDULE
(The question below guided the interviewer during interviews with counsellors.)

1. What approach to physics education in high school seems most appropriate to you? That is, in your opinion, what should be the overall nature of the physics course and which students should be encouraged to take physics?

   Guidelines:

   a. Should physics be taught in such a way as to appeal to all students or just to specific groups?

   b. Should high school physics be offered primarily for the college bound students, especially those who might major in the sciences, or should physics be considered an essential element in the general education of any high school student?

   c. Which physics course would best serve the needs of the students in your school, one that stressed laboratory experimentation, one that stressed applications of higher mathematics to physical problems, or one that stressed the cultural and historical values associated with physics and physicists?

2. How do curriculum innovations take place in your school?

   Guidelines:

   a. Who initiates curriculum innovations?

   b. What are the roles and responsibilities of teachers, department heads, curriculum coordinators, administrators, counsellors, school board members, etc., in curriculum innovation?

   c. Is there a well defined procedure to be followed? Who is involved?

   d. Who has a veto over suggested curriculum innovations? Under what conditions can a veto be exercised?

   e. Who is the most important person in determining if a suggested curriculum innovation will be adopted?

3. Are the views of students towards studying physics undergoing changes?

   Guidelines:

   a. Do you find many students who are interested in physics as a career or as a college major? Do you think that students who choose physics today are motivated differently than students who chose physics in recent years?

   b. Do students choose not to study physics because they feel it is too difficult? Do students choose to study physics because they feel that it is intellectually exciting and challenging?

   c. What kind of images do you think students have of what physics is and what a physicist does?

   d. How do students view science and scientists in relation to current issues in America and the world?